

NASA Contractor Report 178359

# Crew Procedures for Microwave Landing System Operations

Leland G. Summers

McDonnell Douglas Corporation  
Douglas Aircraft Company  
Long Beach, California 90846

Contract NAS1-18028  
November 1987

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National Aeronautics and  
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## SUMMARY AND INTRODUCTION

This report presents the results of a study sponsored jointly by the FAA and NASA as part of the NASA Advanced Transport Operating Systems (ATOPS) Technology Studies contract (NAS1-16202). The objective of this study was to identify crew procedures in microwave landing system (MLS) operations and to obtain a preliminary assessment of crew workload.

Crew procedures specific to MLS operations are the selection and execution of the approach path, and will depend on the airborne equipment used. The minimum navigation equipment required will be an MLS receiver, precision distance measuring equipment (DME/P), and a control panel. This equipment will be coupled to an autopilot to provide autoland capability or flight director steering commands. Only straight-in or instrument landing system (ILS) "look-alike" approaches can be flown with the minimum equipment complement. If a guidance computer similar to a course-line computer is added to the minimum complement, then segmented or curved approaches can be flown, but the crew must enter the flight segment data into the computer on-line. A third configuration, adding a flight segment data base to the guidance computer, must be included to utilize the MLS system's full potential. This allows flying complex approaches with preloaded flight segments or way points.

Crew tasks were identified using the above three equipment complements for MLS approach and precision departure scenarios, and the scenarios were based upon two objectives: circumventing noise-sensitive areas and terrain clearance. The approach scenarios were a segmented path, a multisegmented path, and a segmented glide slope using Runway 15 at Burbank Airport in California. Since these approaches required guidance algorithms, only equipment complements that included a guidance computer were used and these were compared to an ILS approach to Burbank Runway 7. Crew tasks were identified for precision departure and missed approach scenarios using the Quiet Nine departure from San Francisco Airport.

Workload comparisons between the approaches were made using a task-timeline analysis program that obtains workload indexes, i.e., the ratio of the time tasks require to the time available for them. The results of the workload comparisons found that only approaches and departures with the simple guidance computer, where the crew enters the way point data on-line, showed a significant increase in workload over ILS approaches and normal departures. However, the workload even for this equipment complement was within the capacity of the two crew members for the scenarios evaluated in this study. Scenarios using more flight segments or way points closer together may overtax the crew.

This is an initial comparative analysis and the results should only be used as an indication of workload differences between MLS and conventional ILS operations. The task-timeline approach to workload analysis has certain limitations that should be considered in applying these results.

## BACKGROUND

The MLS offers a number of technical advantages over the current ILS. The primary one is wide-angle coverage in both azimuth and elevation, as opposed to the ILS system's narrow-beam coverage. This expanded coverage provides the capability of flying different approach paths to the same runway. Complex approach paths, such as curved and/or segmented path approaches, may be flown if proper airborne navigation equipment is used. This allows the circumvention of noise-sensitive areas and terrain, which is not currently possible with the ILS system. Other technical advantages include less radio interference, more operating channels, and higher reliability.

The MLS ground equipment consists of an azimuth transmitter, an elevation transmitter, and DME/P. This equipment provides azimuth and elevation signals, a coded data signal, and precision DME ranging. Properly equipped aircraft may receive these signals for precision guidance.

Use of the MLS depends on the airborne equipment. For existing aircraft the minimum equipment needed is an MLS receiver, a DME/P interrogator, a control panel, the current course deviation indicators (CDIs), and the flight director. This equipment allows angle-only operation or an ILS "look-alike" mode, i.e., the aircraft flies on the centerline or an offset angle of an MLS-instrumented runway and at a selectable elevation angle. To utilize additional benefits of the MLS, a guidance computer is required to process the steering signals for complex approaches. A data base of way points may be required to support the system.

Several current studies have developed guidance algorithms that will allow a pilot or autopilot to fly complex approach paths. Knox (Reference 1) developed both lateral and vertical guidance algorithms for a variety of complex approaches that provide course-deviation and flight-director steering signals for manual control. Piloted simulation evaluations were conducted using electromechanical instrumentation to present the signals. They found that reasonable tracking errors could be obtained with flight-director steering but not with raw CDI data. Feather (References 2 and 3) developed several complex algorithms that provide pitch and roll steering commands to an autopilot. Computer simulations using an MD-80 autopilot and aerodynamics have shown that reasonable tracking errors can be obtained. Both studies used a way point data base composed of distances, altitudes, and speeds to define the complex approach paths.

The crew must be able to manually fly a complex approach *and* set up the guidance computer for it. In Knox's study, selection and initiation of the approach path was an initial condition and crew procedures for path selection were not evaluated.

The objective of this study is to (1) determine what the crew must do to select and initiate a complex approach path — and the implication of these actions on the crew workload, and (2) determine whether it is possible for the crew to enter the way point data manually from approach plates, rather than storing the way points in computer memory.

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## METHOD

The basic approach of this study was to use analytical techniques to estimate crew workload for MLS operations. This analysis included identifying the crew interface, developing approach scenarios, defining crew procedures, and evaluating workload using an analytical model.

Two aircraft control and display interfaces were used. The first was based on the MD-80 flight guidance and control system. MLS functions were added to the radio navigation control panel, and the aircraft displays were left unchanged. The second interface was based on the Sperry flight management system (FMS) that is being developed for the MD-88. This system uses a flight management computer for the guidance algorithms and way point storage, a control display unit (CDU) for the crew interface with the FMS, and an electronic flight instrumentation system (EFIS) for the flight displays.

Approach scenarios were based upon circumventing noise-sensitive areas and clearing terrain at Burbank Airport. This airport is considered one of the prime candidates for MLS operations. San Francisco Airport was selected for precision departures and missed approaches. Again, the departure was based upon circumventing noise-sensitive areas and clearing terrain.

Crew tasks were identified using normal crew procedures with existing equipment, and the only modifications were for MLS operations. All procedures for this study used autopilot and autothrottle operation with an integrated flight guidance and control system. The flight scenarios assumed no contingencies or deviations by the air traffic controller from the planned courses. Wind data were not included in the analysis, and all scenarios assumed no winds aloft.

Crew workload was evaluated using a program developed at Douglas Aircraft Company (Reference 4) to measure workload for verifying aircraft design and certifying aircraft. This program uses a task-time-line methodology to obtain workload indexes. The workload index is the time required for task performance divided by the time available. The impact of MLS operations on crew workload can be estimated by comparing workload indexes for MLS and ILS operations.

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## AIRBORNE EQUIPMENT FOR MLS OPERATIONS

One of this study's basic ground rules was to use existing technology for the guidance computer and flight displays. Another was to evaluate equipment that could be retrofitted into the current air carrier fleet. It was assumed that all aircraft would be equipped with an autopilot that would provide autoland capability and flight director steering commands.

As noted above, the minimum equipment needed for MLS operations would be an MLS receiver, a precision DME interrogator, a control panel, CDIs, and the flight director. This equipment provides precision azimuth, elevation, and range readouts. In addition to the minimum equipment, a guidance computer would provide two functions: guidance algorithms for flying segmented and/or curved approaches, and storage of an approach path data base.

It was decided to use three equipment complements for this evaluation:

- Minimum equipment including the MLS receiver, a DME/P interrogator, and a control panel.
- The above and a guidance computer providing segmented approaches, but without storage of the approach path data base.
- The MLS receiver, the DME/P interrogator, and a flight management system incorporating the guidance algorithms and the approach path data bases.

The first complement provides angle-only operations. The other complements are similar to the operational capability levels selected by the Radio Technical Commission for Aeronautics SC-151 Committee (Reference 5), but do not exactly agree. The second complement is similar to Level I, but the pilot can select one segment at a time and the approaches can be flown by autopilot. The third complement is similar to Level III, which allows the autopilot to fly multiple segments or curved approaches with the pilot monitoring.

### Complement 1

This complement is the most common configuration for retrofitting aircraft that do not have a flight or performance management system. The equipment includes the MLS antenna and receiver, a precision DME interrogator, and modification of the flight guidance and control panel. For the MD-80 this would include modification of the VHF navigation control panel and the addition of the MLS function to the ILS-mode select switch. The modified navigation control panel would include the ability to tune the MLS frequencies and the azimuth angle (as a magnetic bearing angle), the addition of the glide slope angle select control, and a forward/back azimuth select switch. The primary flight instruments would be left unchanged, except that more precise ranges would be presented on the DME indicator.

Figure 1 shows the interrelationships of the MLS with the autopilot and the instrumentation. The MLS readouts will be the course and glide slope deviations on the attitude director indicator (ADI) and horizontal situation indicator (HSI), the bearing of the runway centerline or offset angle on the HSI's course arrow, and the range on the HSI's DME readout. This configuration allows straight-line tracking of the selected azimuth and elevation angles, and it does not require a guidance computer. The only precision

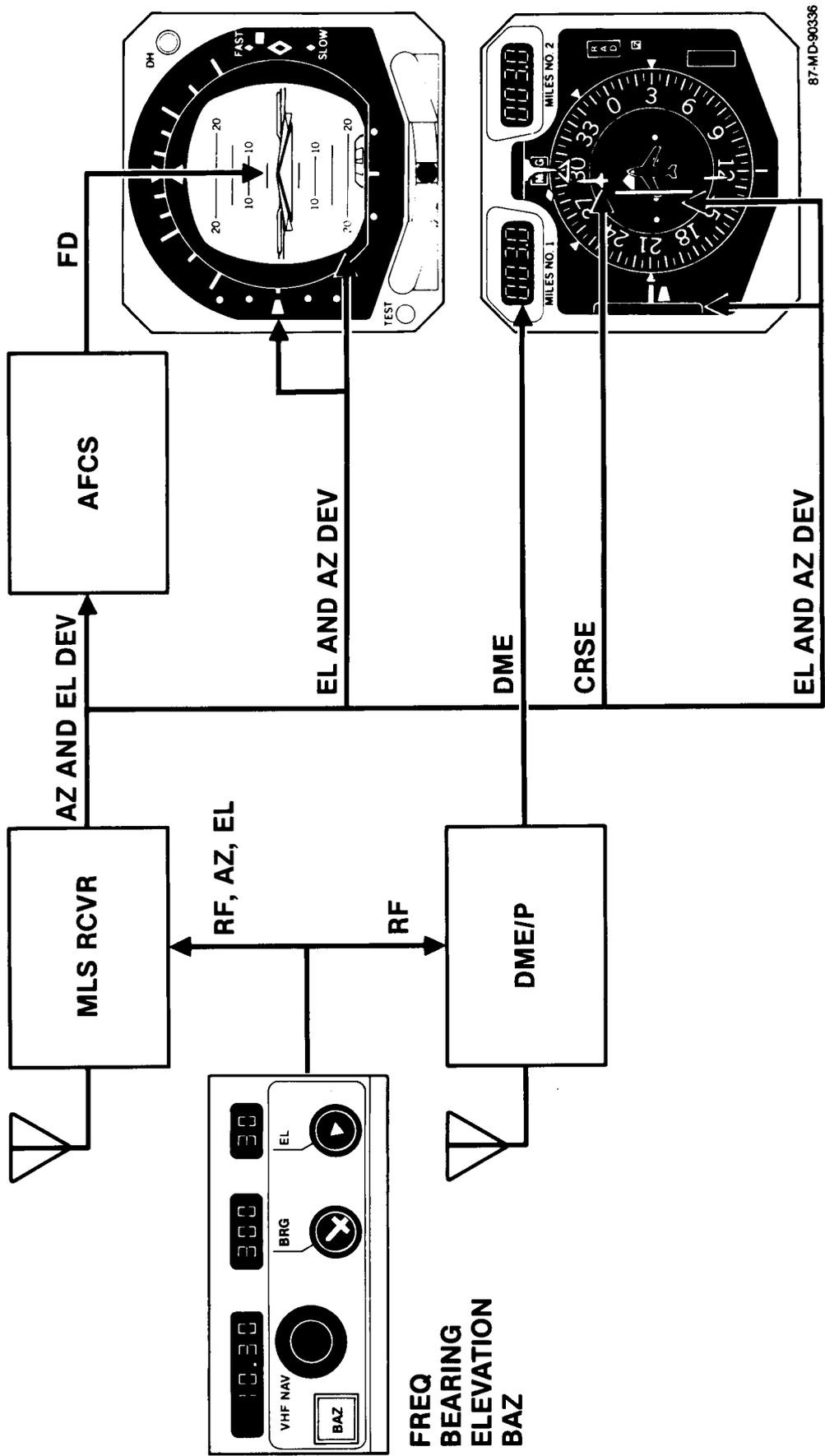


FIGURE 1. SYSTEM BLOCK DIAGRAM FOR EQUIPMENT COMPLEMENT 1

approaches this system is capable of flying on the centerline of the runway, or at an offset angle from the centerline if a visual transition is made at the minimum descent altitude. It does allow selection of different glide slope angles.

Crew procedures for this mode of operation are essentially the same as for ILS. The crew selects MLS frequency, runway bearing, and glide slope angle on the VHF NAV panel. In the VOR/LOC mode, the autopilot tracks the selected azimuth angle. In the ILS/MLS or autoland mode it tracks both the azimuth and elevation angles. The azimuth and glide slope deviations are displayed on the ADI and HSI CDIs. The deviation signals drive the autopilot and the flight director steering commands. The crew will be able to monitor the approach by the course needle and the precision DME readout, as well as the flight director steering signals.

### **Complement 2**

In addition to the MLS receiver and antenna, this complement contains a guidance computer for segmented or curved approaches. The crew must insert the way point data for a segment on-line during the approach. The way point data include the bearing, elevation, and distance of the way point from the MLS datum point. When the system is engaged, the computer calculates a course from the aircraft's present position to the way point. The system block diagram is shown in Figure 2. The crew interface for the way point entry is a modified VHF navigation control panel allowing entry of the bearing, elevation, and range, and selection of the forward or back azimuth antenna. Steering deviation signals are fed to the autopilot and the instruments. The way point's course and range are indicated by the course arrow and the left DME readout of the HSI. The course and range to the MLS datum point are indicated by the second course arrow and the right DME readout.

To fly a segmented flight path approach, the crew reads the bearing, elevation, and range of a way point to the runway from an approach plate and enters these values into the navigation panel after tuning the MLS frequency. After engaging the MLS mode, they monitor the left DME readout and when the aircraft is within a predetermined distance from the way point, e.g., 1.0 nautical mile, the crew enters the next way point values into the navigation panel. This is repeated until the runway bearing and the 0 range are entered. When this occurs, the system automatically uses the threshold distance and minimum glide slope contained in the MLS data link. The limitation of this procedure is the crew's ability to make the way point entries while flying and/or monitoring the aircraft.

With this complement, the crew has to anticipate when to enter the next way point values into the VHF NAV control panel by monitoring the distance to the way point. The crew selects the MLS frequency and the way point bearing, elevation, and range from the approach plate. By selecting the VOR/LOC mode, the aircraft will capture and track the course to the way point. By selecting the ILS/MLS or autoland mode, it will capture and track the way point course and the glide slope angle. A crew member monitors distance to the way point, and when it is within a predetermined distance, he enters the next way point data.

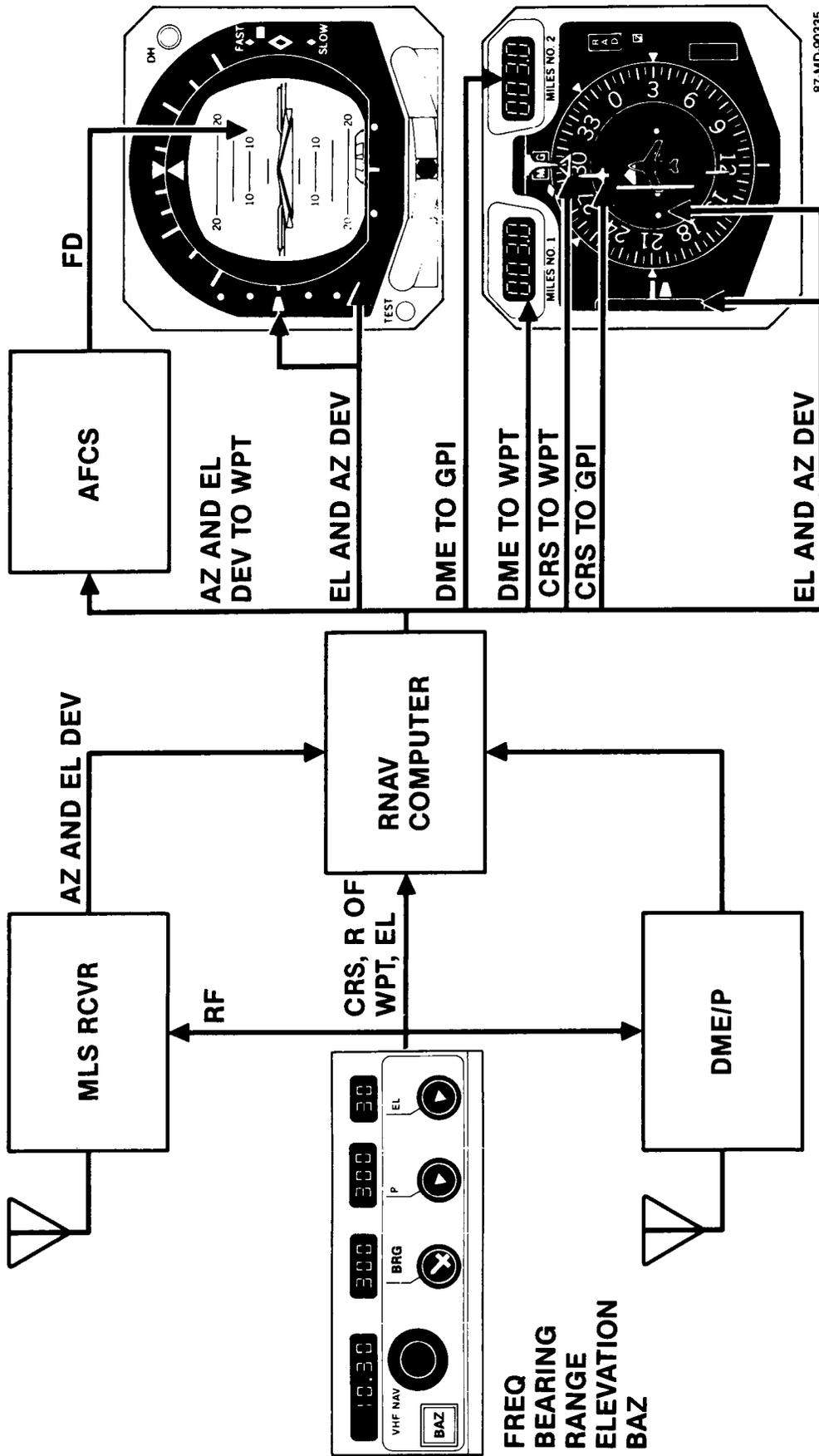


FIGURE 2. SYSTEM BLOCK DIAGRAM FOR EQUIPMENT COMPLEMENT 2

### Complement 3

This equipment complement assumes that the MLS guidance functions are included in the FMS. The FMS will use the deviation signals from the MLS receiver and the output of the DME/P interrogator. The guidance laws and way points stored in the FMS computer are used to generate steering commands for the autopilot and guidance information for the flight displays. The system block diagram is shown in Figure 3 with electronic flight instrumentation system displays. The crew interface described in this report is based on the Sperry flight management system that is being developed for the MD-88, and is similar to the Boeing 767 and 757 FMS.

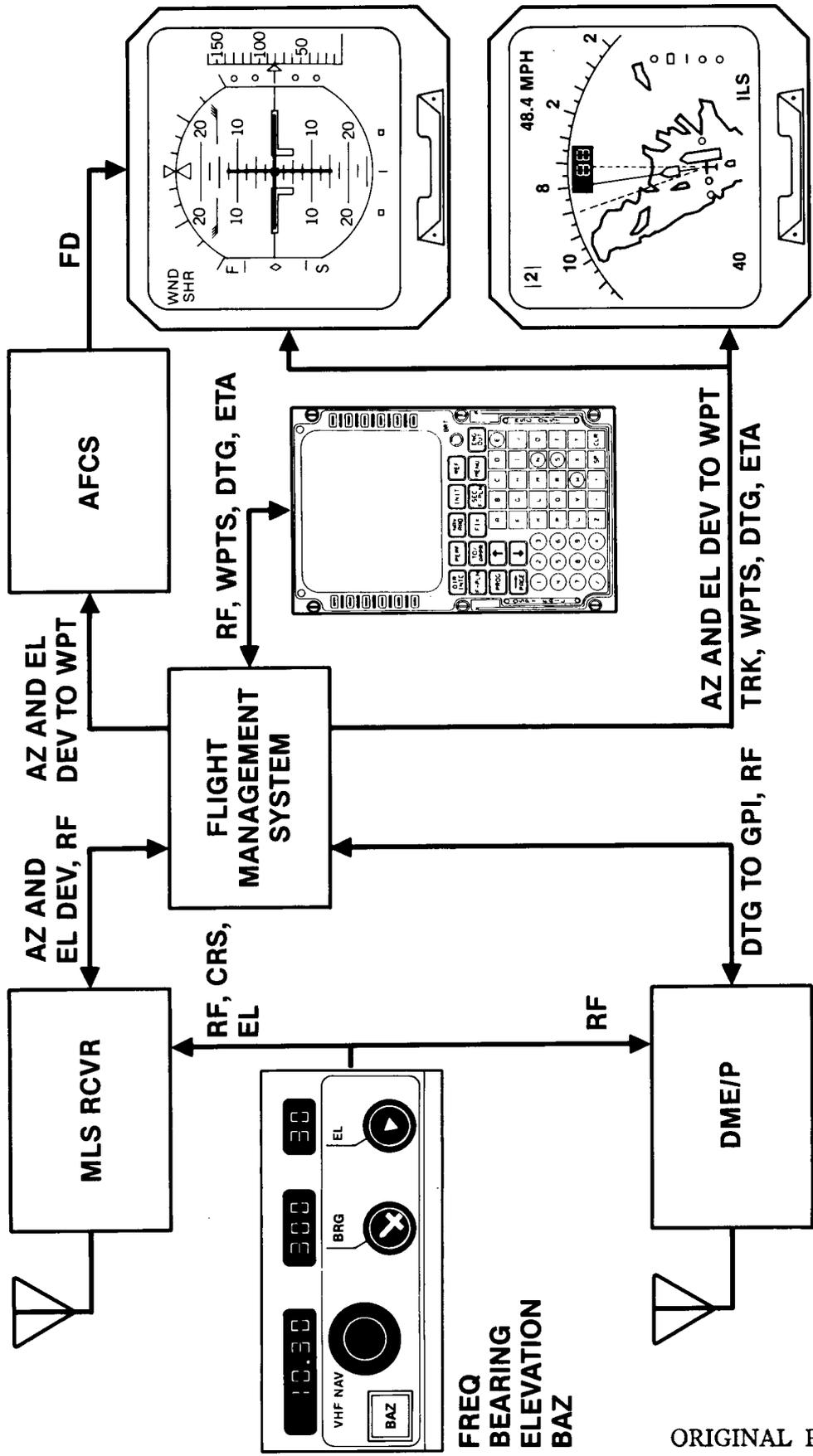
The equipment complement includes the flight management computer that contains the navigation and performance data base. The computer is controlled by a CDU located in the forward pedestal. The route information can be displayed either on the CDU or the EFIS navigation display (ND). The FMS can be connected to the autopilots, the flight directors, and autothrottles for both lateral and vertical guidance. The radio navigation panel on the glareshield allows manual tuning of the VOR and the MLS receivers. The FMS outputs and the flight director steering commands are fed to the EFIS. The ND can show route information similar to the symbology found in aeronautical charts.

The MLS approach paths are defined by way points, i.e., the end points of the straight-line flight segments or legs. The guidance laws generate a curved path based upon the way points. These way points will be located in the FMS's navigation data base. Predetermined approach paths consisting of a series of way points will be treated like standard terminal arrival routes (STARs) and will be located in the FMS's departure/arrival (DEP/ARR) book. The crew can select the approach paths and insert them into the flight plan as they would STARs or an arrival runway. The crew can alter the approach paths or enter new ones into the computer. This ability will be the same as altering way points in a flight plan or building a flight plan.

It is assumed that the MLS receiver is manually tuned. When the receiver is tuned to the MLS frequency and the way points are included in the active route plan, the FMS will switch from a lateral-vertical navigation mode to the MLS navigation mode when either the MLS or autoland mode is engaged and the aircraft is receiving valid MLS signals. Before the approach, the crew can insert the approach path via the CDU by selecting the appropriate approach-path pages and executing.

The normal crew procedure for inserting an approach path into the flight plan will be to select the DEP/ARR page on the CDU. Then, using the line select keys, the crew selects the index, runway, MLS approach, STARs, and transition. Pressing the execute key enters the approach path into the active flight plan. The way points will appear on the legs page of the CDU and on the ND. Examples of the CDU pages are shown in Figure 4. The first line of a way point entry on the legs page contains the course, leg distance, and glide slope angle at the way point. The second line contains the way point name and the calculated speed and altitude at way point crossing.

Approach paths may be altered from stored paths — either on the route or the legs page — as the active route is altered for other phases of flight. This includes deleting a way point, linking discontinuous legs, inserting way points and flying directly to a way point, or intercepting a leg. In addition, way points not in the data base may be added by specifying their bearing, elevation, and distance to the MLS datum point.



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FIGURE 3. SYSTEM BLOCK DIAGRAM FOR EQUIPMENT COMPLEMENT 3

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KBUR ARRIVALS		
STARS	RTE 1	APPROACHES
LYNXX.2		ILS 07
		MLS 15-1
		MLS 15-2
		MLS 15-3
		RUNWAYS
		7
-----		
< INDEX		ROUTE >

ARRIVAL PAGE FOR BURBANK

ACT	RTE 1	2/3
VIA		TO
DIRECT		TWINE
		(INTC)
MLS 15-1		RWY 15
MISSED APPR		VNY
-----		
< RTE 2		

ROUTE PAGES

ACT	RTE 1	LEGS
087° TWINE	13.3 NM	250/5000
087° MLS 01	12.3 NM	3.8° 170/1450
152° RW 15	3.6 NM	3.8° 170/1400
152° (1,400)	1 NM	---/1400
310° VNY		---/4000
-----		
< RTE 2 LEGS		RTE DATA >

ROUTE LEGS PAGE

FIGURE 4. FMS CDU PAGES WITH MLS APPROACHES

## MLS SCENARIOS

### Approach Scenarios

The MLS scenarios selected for this study were designed to evaluate crew workload for MLS operations using the different equipment complements, and to compare the workloads of MLS and ILS approaches. Selection criteria were based upon crew operations, not guidance algorithms. Other criteria were based upon airport sites that have special requirements for MLS operations, such as circumventing noise-sensitive areas and terrain clearance.

Four approach paths were selected that differ in the degree of complexity:

- A straight-in ILS approach.
- A single-segmented path approach.
- A double-segmented path approach.
- A segmented glide slope approach.

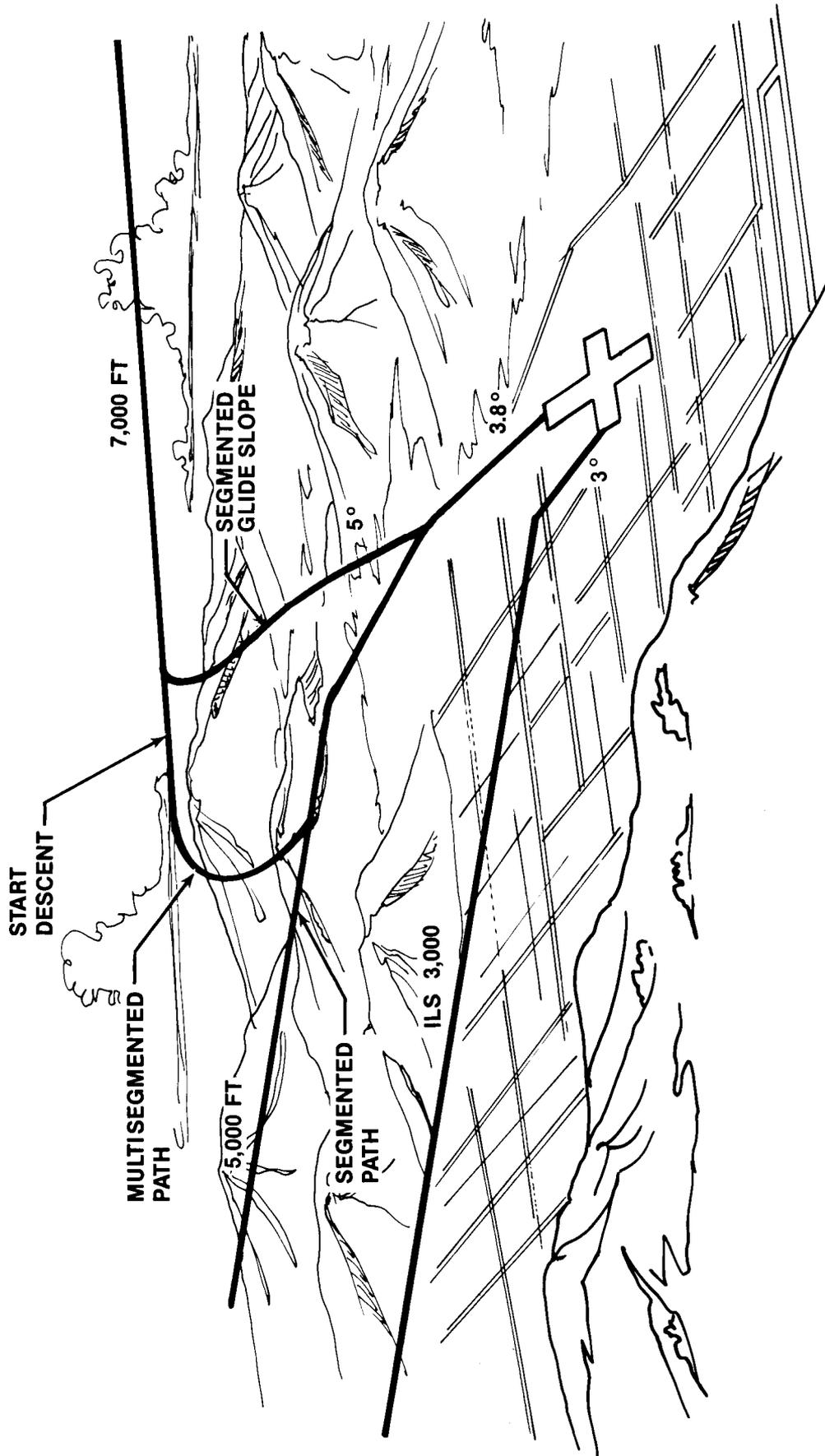
Only ILS operations were analyzed for the straight-in approach because there is little difference between them and the MLS straight-in approach. Equipment Complements 1 and 3 were used for the ILS approach. In current FMS systems (Complement 3) the ILS operations are not part of the FMS functions, and after the aircraft is on the intercept heading the ILS functions are the same as for Complement 1. Analysis of these two approaches served as a baseline for comparing MLS operations. Since the remaining approaches required segmented guidance, equipment Complements 2 and 3 were used.

The airport selected for these approaches was California's Burbank Airport. Burbank has two runways: Runway 7, which is instrumented for ILS, and Runway 15, which uses a visual approach. The approach to Runway 7 traverses noise-sensitive areas, and a straight-in approach to Runway 15 is limited by mountainous terrain. If Runway 15 was equipped with MLS, either segmented path or segmented glide slope approaches would circumvent the noise-sensitive areas and avoid the terrain. Figure 5 illustrates the situation at Burbank Airport.

In detail, the scenarios developed were:

- A straight-in ILS approach to Burbank Runway 7 from a Fillmore VOR transition. ILS scenarios were developed using equipment equivalent to Complements 1 and 3.
- An MLS segmented path approach from a Fillmore VOR transition to the Four Stacks visual approach to Burbank Runway 15. Equipment Complements 2 and 3 were used.
- An MLS multisegmented path approach from a Palmdale transition and the Lynxx Two arrival to the Four Stacks visual approach to Burbank Runway 15. This uses the same final approach as the single-segmented scenario but requires a precision transition from the Van Nuys VOR without radar vectors. Equipment Complements 2 and 3 were used.

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FIGURE 5. MLS APPROACHES TO BURBANK AREA AIRPORT

- A segmented, straight-in glide slope approach to Burbank Runway 15 from a Palmdale transition. This requires an initial glide slope of 5 and a final glide slope of 3.8. Equipment Complements 2 and 3 were used.

The impact of MLS operations will be on crew procedures for guidance and control of the aircraft. Other crew activity will remain essentially the same. ATC communications may be reduced because approach control can assign aircraft to an approach path without vectoring. In autopilot operations the main crew activity will be the selection of navigational aids, selection of course and/or heading, engagement of the autopilot, and monitoring aircraft performance. Manual control operation with a flight director will include the same crew activities, with the addition of one crew member being active on the controls at all times. However, manual operation with a flight director was not analyzed because of the workload model's limitation.

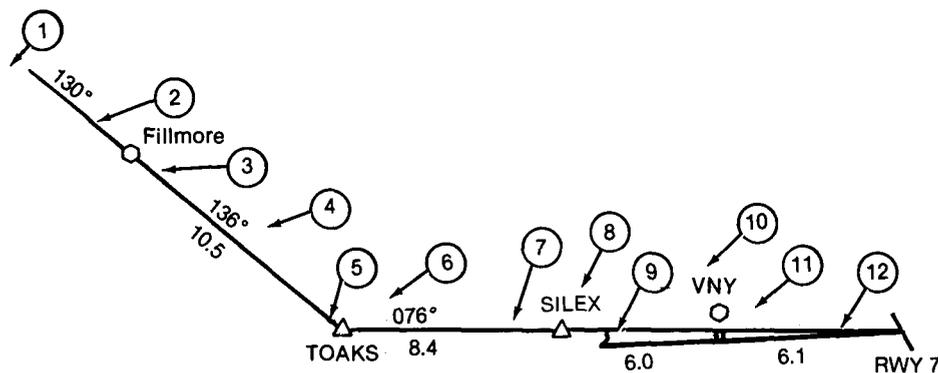
Crew procedures for the guidance and control activity were identified for each of the scenarios. The plan of each approach and a listing of crew guidance and control actions are presented in Figures 6-13, which also identify points at which crew actions occur.

#### **Precision Departure and Missed Approach Scenarios**

Potential uses of MLS are precision departures and missed approaches utilizing the system's back azimuth antenna. Again, the basic reasons for precision departures are to circumvent noise-sensitive areas and avoid terrain. San Francisco Airport's Runway 28 is one site that may be used to test precision departures for these objectives. As Figure 14 shows, the airport's Quiet Nine visual (VFR) departure requires a positive rate of ascent followed by a steep right turn to heading 030 in order to miss terrain and intercept the 342 radial from San Francisco VOR.

Guidance procedures for a normal instrument (IFR) departure, Rebas One, are shown in Figure 15. This is a straight climb until 6 DME, and the crew turns to a heading of 040. An MLS precision departure for Quiet Nine is shown in Figure 16 for equipment Complement 2 and in Figure 17 for Complement 3. This assumes that the back azimuth antenna is skewed off Runway 28 centerline so that the way point is within coverage. For the precision departure the crew selects the MLS frequency, the back azimuth function, and the departure path before takeoff. After ascent is established, the crew engages the autopilot and the MLS. The crew monitors the turn and, within 0.5 DME of the way point, they insert the next way point and monitor the turn to 342. For equipment Complement 3 with the FMS, the departure is preselected and the only crew functions are monitoring aircraft position and performance.

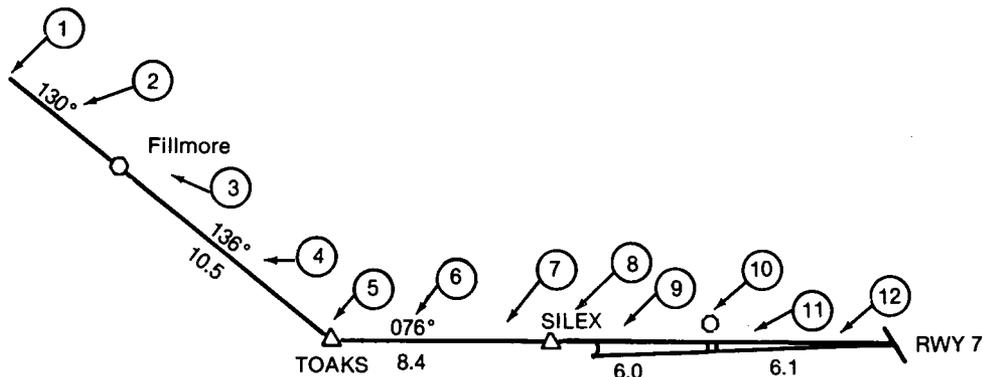
The procedure for the missed approach requires switching to the back azimuth function when the aircraft reaches an area covered by both forward and back azimuth antennas. When the back azimuth signal is received, it will be annunciated. For equipment Complement 2, it is assumed that the crew performs this action. After engaging the go-around mode and a valid back azimuth signal is received, the crew selects the back azimuth function and enters the bearing and distance to the way point. For equipment Complement 3, it is assumed that the switching is performed by the FMS. The crew would add the missed approach path to the flight plan. Normally this would occur when the MLS approach path and runway are selected. One of two actions would be required: line selection of the missed approach path



1. VHF NAV Receivers 1 and 2 are tuned to the Fillmore VOR. Course is set to 130. Aircraft is flying at 10,000 feet.
2. L.A. Center instructs crew to descend to 4,000 feet at 7 DME to Fillmore. Crew sets altitude at 4,000 feet and arms. Crew monitors when aircraft is 7 DME to Fillmore and rotates pitch wheel to desired descent rate.
3. When crossing over Fillmore VOR, crew changes course to 136 on both VHF NAV Receivers 1 and 2 and monitors turn.
4. Aircraft levels off at 4,000 feet. Crew monitors altitude capture.
5. Crew contacts Burbank approach. Approach instructs crew to turn to heading 076 at TOAKS. Crew monitors when aircraft is 10.5 DME from Fillmore and sets heading to 076. Crew monitors turn.
6. Crew tunes ILS Receivers 1 and 2 to Burbank ILS and sets inbound course 076.
7. Approach control instructs crew to descend to 3,000 feet and clears crew for final approach. Crew sets altitude to 3,000 feet and arms. Crew rotates pitch wheel to desired descent rate.
8. Aircraft levels off at 3,000 feet. Crew monitors altitude capture.
9. Crew monitors localizer capture. Crew engages autoland.
10. Crew monitors glide slope capture.
11. Crew monitors outer marker crossover.
12. Crew monitors middle marker crossover.

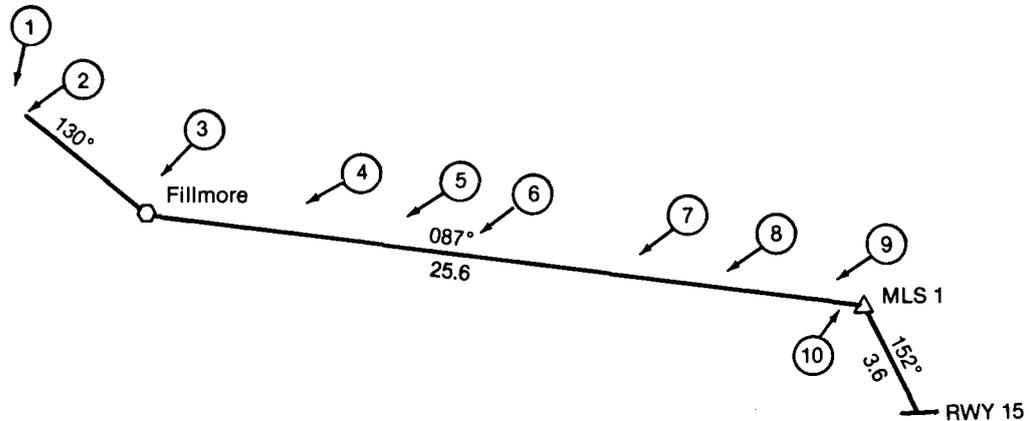
**FIGURE 6. GUIDANCE PROCEDURES FOR AN ILS APPROACH TO BURBANK RUNWAY 7 — EQUIPMENT COMPLEMENT 1**

from a page in the DEP/ARR book, or entering the course on the route page via the CDU. Once the go-around mode is selected, the lateral guidance would execute the missed approach. Procedures for a missed approach to San Francisco Runway 28 using the Quiet Nine departure are shown in Figures 18 and 19 for equipment Complements 2 and 3, respectively.



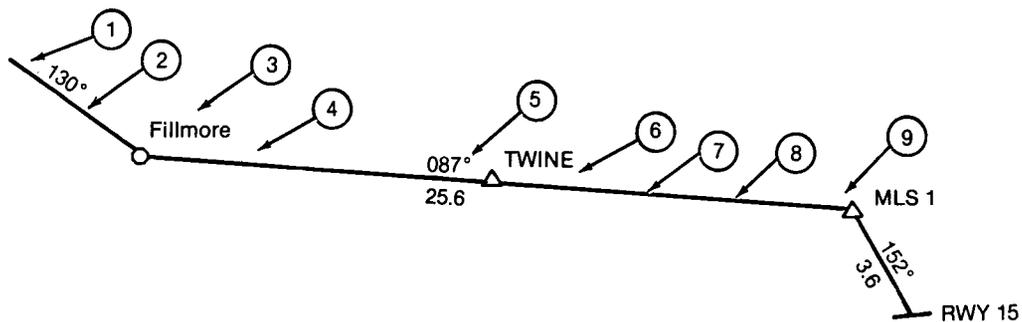
1. FMS lateral (LNAV) and vertical (VNAV) navigation modes are engaged.
2. L.A. Center instructs crew to descend to 4,000 feet at TOAKS. Crew sets altitude at 4,000 feet on the FGCP, enters 4,000 feet into TOAKS WPT, and executes on the CDU. Crew monitors the descent.
3. Crew monitors the way point crossing and turn at Fillmore.
4. Crew contacts Burbank approach. Approach instructs crew to turn to heading 076 at TOAKS. Crew selects ILS RWY 7 on DEP/ARR page and executes.
5. Crew monitors turn at TOAKS and level-off at 4,000 feet.
6. Crew tunes ILS Receivers 1 and 2 to Burbank ILS and sets inbound course 076.
7. Approach control instructs crew to descend to 3,000 feet and clears crew for final approach. Crew sets altitude to 3,000 feet and arms. Crew rotates pitch wheel to desired descent rate.
8. Aircraft levels off at 3,000 feet. Crew monitors altitude capture.
9. Crew monitors localizer capture. Crew engages autoland.
10. Crew monitors glide slope capture.
11. Crew monitors outer marker crossover.
12. Crew monitors middle marker crossover.

**FIGURE 7. GUIDANCE PROCEDURES FOR AN ILS APPROACH TO BURBANK RUNWAY 7 — EQUIPMENT COMPLEMENT 3**



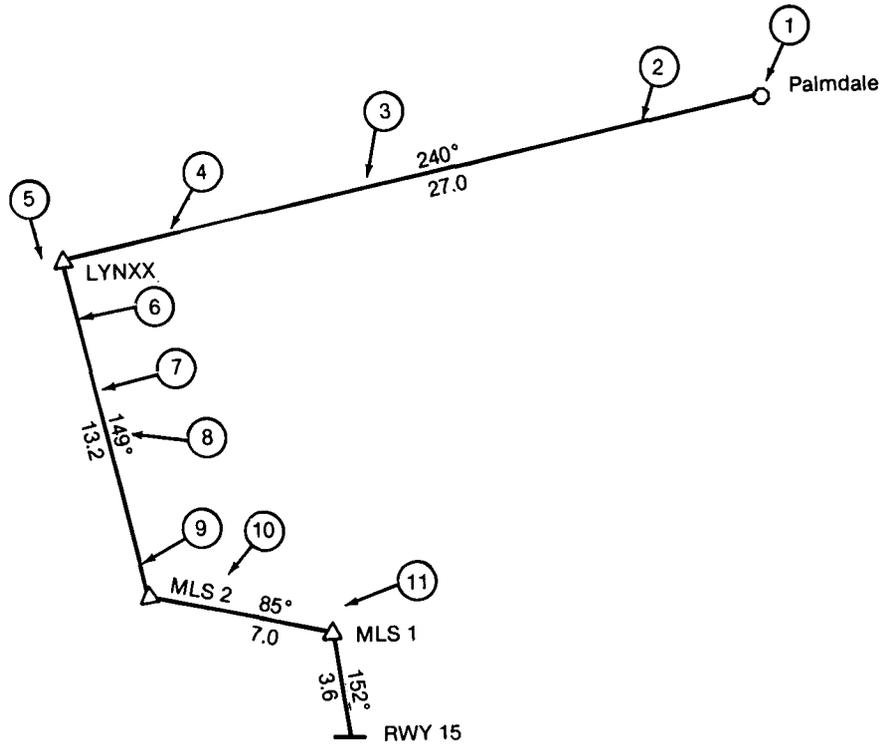
1. VHF NAV Receivers 1 and 2 are tuned to the Fillmore VOR. Course is set to 130. Aircraft is flying at 10,000 feet.
2. L.A. Center instructs crew to descend to 5,000 feet at 7 DME to Fillmore. Crew sets altitude to 5,000 feet and arms. Crew monitors when aircraft is 7 DME to Fillmore and rotates pitch wheel to desired descent rate.
3. When crossing over Fillmore VOR, crew changes course to 087 on both VHF NAV Receivers 1 and 2 and monitors turn.
4. Aircraft levels off at 5,000 feet. Crew monitors altitude capture.
5. Crew contacts Burbank approach. Approach instructs crew to maintain heading of 087 for MLS01 approach to RWY 15. Crew sets heading of 087 and arms.
6. Crew tunes MLS Receivers 1 and 2 to MLS Burbank, and sets bearing to 152, elevation to 3.8, and range to 3.6.
7. Approach control clears for final approach. Crew engages autoland.
8. Crew monitors localizer capture.
9. Crew monitors glide slope capture.
10. Crew monitors when aircraft is 1.0 DME from MLS01, and sets range to 0.0. Crew monitors turn to final course.

**FIGURE 8. GUIDANCE PROCEDURES FOR AN MLS SEGMENTED APPROACH FROM FILLMORE TRANSITION TO BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 2**



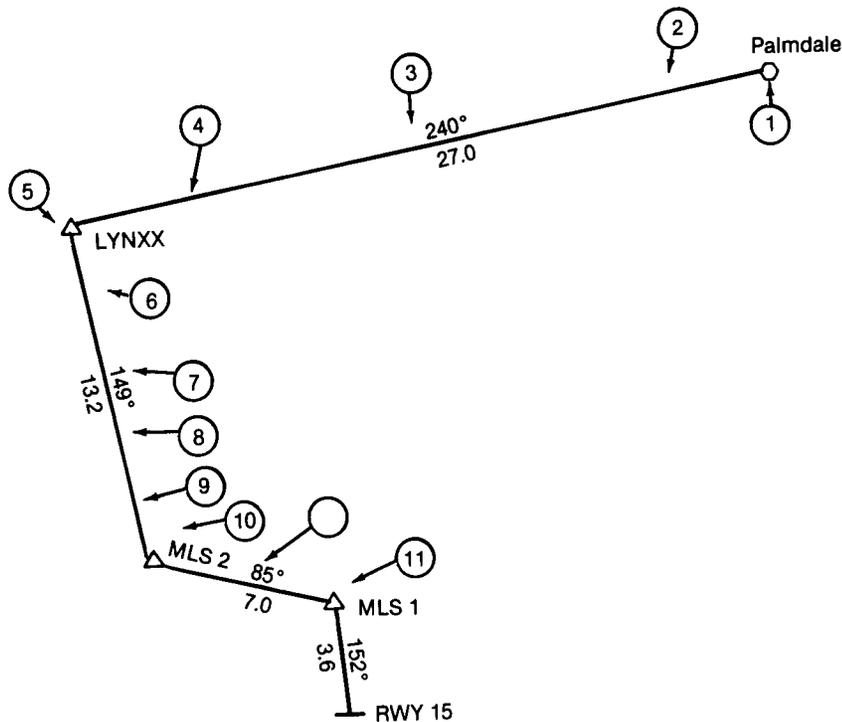
1. FMS lateral (LNAV) and vertical (VNAV) navigation modes are engaged.
2. L.A. Center instructs crew to descend to 5,000 feet at TWINE. Crew sets altitude at 5,000 feet on the FGCP, enters 5,000 feet into TWINE WPT, and executes on the CDU. Crew monitors the descent.
3. Crew monitors the way point crossing and turn at Fillmore.
4. Crew contacts Burbank approach. Approach instructs crew to continue on course to MLS01 approach to RWY 15. Crew selects MLS01 in DEP/ARR book and executes on CDU. Crew tunes MLS Receivers 1 and 2 to Burbank.
5. Crew monitors TWINE crossing and altitude capture.
6. Approach control clears for final approach. Crew engages autoland mode.
7. Crew monitors localizer capture.
8. Crew monitors glide slope capture.
9. Crew monitors turn at MLS01 to final course.

**FIGURE 9. GUIDANCE PROCEDURES FOR AN MLS SEGMENTED APPROACH FROM FILLMORE  
TRANSITION TO BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 3**



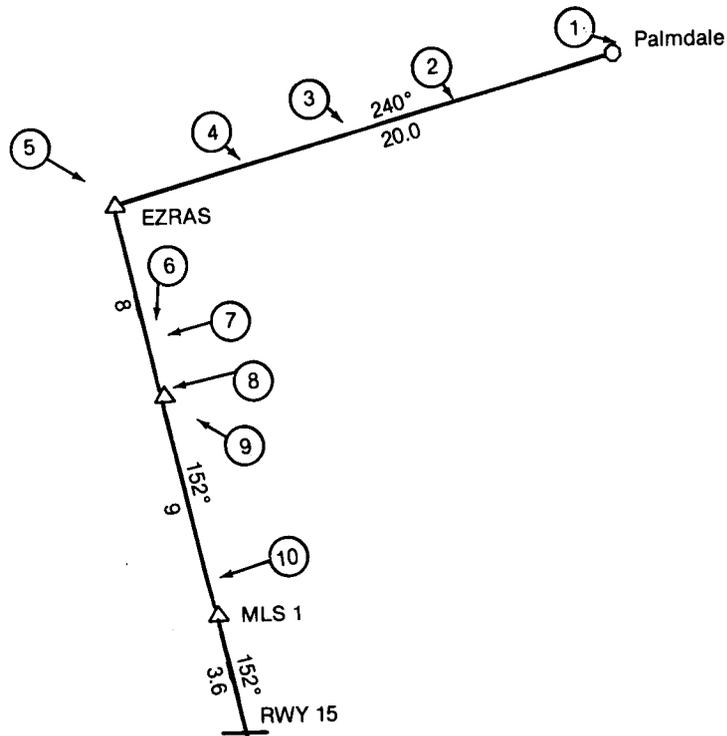
1. VHF NAV Receivers 1 and 2 are tuned to Palmdale VOR, and course is set to 240. Aircraft is flying at 10,000 feet. L.A. Center instructs crew to descend to 7,000 feet at Palmdale. Crew sets altitude to 7,000 feet, arms, and rotates pitch wheel to desired descent rate.
2. Crew monitors level-off at 7,000 feet.
3. Crew tunes VHF NAV 2 to Van Nuys VOR.
4. Crew contacts approach control. Approach instructs crew to turn to heading of 149 and descend to 5,000 feet at LYNXX. Crew sets altitude at 5,000 feet and arms.
5. Crew monitors when Palmdale DME is 27 and Van Nuys DME is 18, sets heading at 149, and rotates pitch wheel to desired descent rate. Crew monitors turn and descent.
6. Crew tunes MLS Receivers 1 and 2 to Burbank MLS, and sets bearing to 106, elevation to 4.5, and range to 9.0.
7. Crew monitors level-off at 5,000 feet.
8. Approach control clears for final approach. Crew engages autoland. Crew monitors localizer capture.
9. Crew monitors glide slope capture.
10. Crew monitors when aircraft is 1.0 DME from MLS02, and sets bearing to 152, elevation to 3.8, and range to 3.6. Crew monitors turn and localizer track.
11. Crew monitors when aircraft is 1.0 DME from MLS01, and sets range to 0.0. Crew monitors turn to final course.

**FIGURE 10. GUIDANCE PROCEDURES FOR AN MLS MULTISEGMENTED APPROACH FROM PALMDALE TO A LYNXX ARRIVAL AT BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 2**



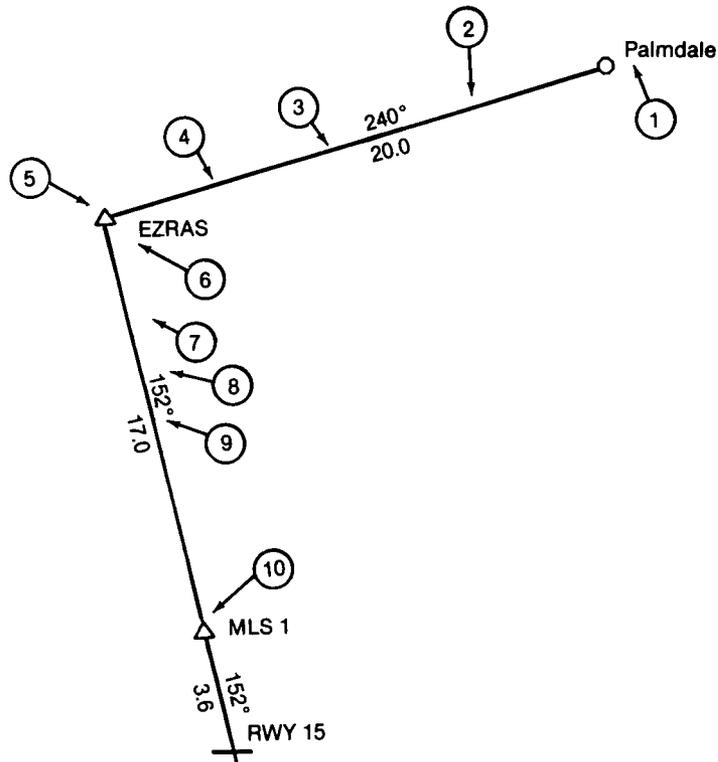
1. Palmdale transition to LYNXX arrival has been previously entered into active route. VHF NAV Receivers 1 and 2 are tuned to Palmdale VOR. Aircraft is in LNAV-VNAV mode. Aircraft is flying at 10,000 feet. Crew monitors way point crossing and turn to 240.
2. L.A. Center instructs crew to descend to 7,000 feet. Crew sets altitude to 7,000 feet on the FGCP, enters 7,000 feet at LYNXX way point, and executes on the CDU.
3. Crew tunes VHF NAV 2 to Van Nuys VOR.
4. Crew contacts approach control. Approach instructs crew to turn to course of 149 for a MLS02 approach and descend to 5,000 feet at LYNXX. Crew enters MLS2 from the DEP/ARR book into the active route and sets altitude at 5,000 feet and arms.
5. Crew monitors LYNXX crossing and turn to 149 course.
6. Crew rotates pitch wheel to desired descent rate and tunes VHF NAV Receivers 1 and 2 to Burbank MLS.
7. Crew monitors level-off at 5,000 feet.
8. Approach control clears for final approach. Crew engages autoland. Crew monitors localizer capture.
9. Crew monitors glide slope capture.
10. Crew monitors MLS02 crossing and turn to course 085.
11. Crew monitors MLS01 crossing and turn to course 152.

**FIGURE 11. GUIDANCE PROCEDURES FOR AN MLS MULTISEGMENTED APPROACH FROM PALMDALE TRANSITION TO LYNXX ARRIVAL AT BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 3**



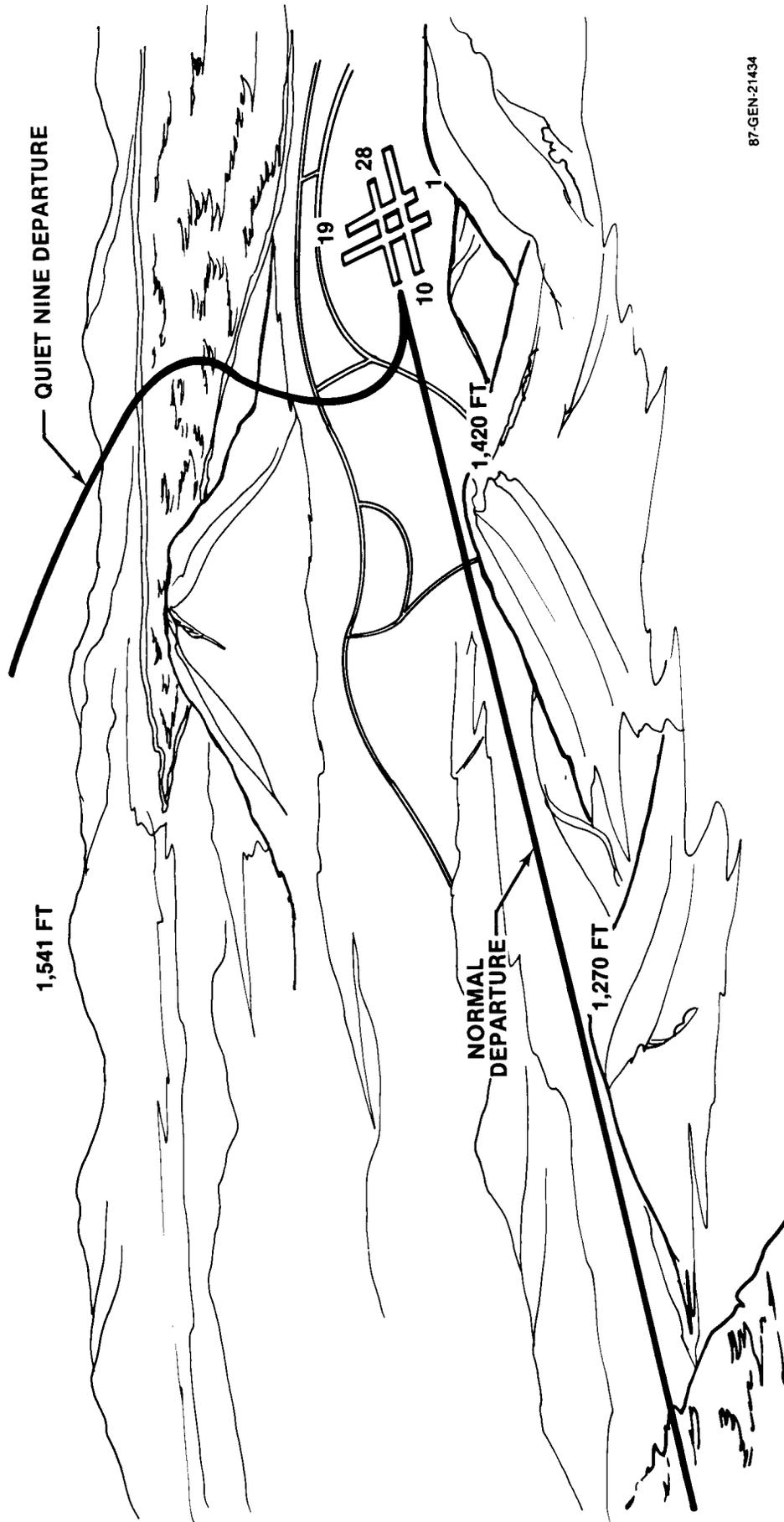
1. VHF NAV Receivers 1 and 2 are tuned to Palmdale VOR, and course is set to 240. Aircraft is flying at 10,000 feet. L.A. Center instructs crew to descend to 7,000 feet at Palmdale. Crew sets altitude to 7,000 feet, arms, and rotates pitch wheel to desired descent rate.
2. Crew monitors level-off at 7,000 feet.
3. Crew tunes VHF NAV Receiver 2 to Van Nuys VOR.
4. Crew contacts approach control. Approach instructs crew to turn to heading of 152 and hold an altitude of 7,000 feet at EZRAS for MLS04 approach.
5. Crew monitors when Palmdale DME is 20 and Van Nuys DME is 18 and sets heading to 152. Crew monitors turn.
6. Crew tunes MLS Receivers 1 and 2 to Burbank MLS, and sets bearing to 152, elevation to 3.8, and range to 3.6.
7. Approach control clears for final approach. Crew engages VOR/LOC mode.
8. Crew monitors localizer capture. At 12.6 DME, crew engages autoland mode.
9. Crew monitors glide slope capture and descent.
10. Crew monitors when DME is 1.0 from MLS01, sets range to 0.0, and monitors change in glide slope.

**FIGURE 12. GUIDANCE PROCEDURES FOR AN MLS SEGMENTED GLIDE SLOPE APPROACH FROM PALMDALE TRANSITION TO BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 2**



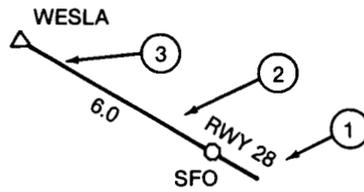
1. Palmdale transition to EZRAS has been previously entered into active route. VHF NAV Receivers 1 and 2 are tuned to Palmdale VOR. Aircraft is in LNAV-VNAV mode. Aircraft is flying at 10,000 feet. Crew monitors way point crossing and turn to 240.
2. L.A. Center instructs crew to descend to 7,000 feet. Crew sets altitude to 7,000 feet on the FGCP, enters 7,000 feet at EZRAS way point, and executes on the CDU.
3. Crew tunes VHF NAV Receiver 2 to Van Nuys VOR.
4. Crew contacts approach control. Approach instructs crew to change course to 152 and hold altitude of 7,000 feet at EZRAS for the segmented glide slope approach. Crew enters MLS4 from the DEP/ARR book into the active route.
5. Crew monitors way point crossing and turn at EZRAS.
6. Crew tunes MLS Receivers 1 and 2 to Burbank.
7. Approach control clears for final approach. Crew engages autoland.
8. Crew monitors localizer capture.
9. Crew monitors glide slope capture and descent.
10. Crew monitors change in glide slope at MLS01.

**FIGURE 13. GUIDANCE PROCEDURES FOR AN MLS SEGMENTED GLIDE SLOPE APPROACH FROM PALMDALE TRANSITION TO BURBANK RUNWAY 15 — EQUIPMENT COMPLEMENT 3**



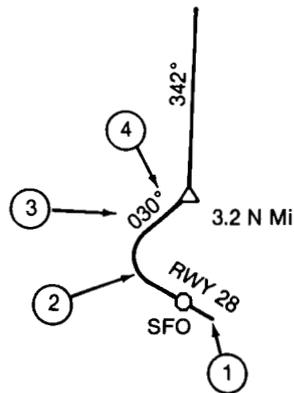
87-GEN-21434

FIGURE 14. MLS PRECISION DEPARTURE FROM SAN FRANCISCO AIRPORT



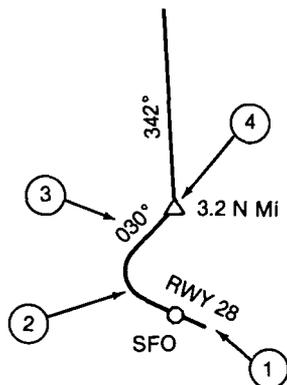
1. Crew tunes VHF NAV Receivers 1 and 2 to San Francisco VOR and sets course to 281.
2. Crew engages autopilot after attaining a positive rate of climb.
3. At 6 DME, crew sets heading to 040 and engages heading select mode.

**FIGURE 15. GUIDANCE PROCEDURES FOR A NORMAL IFR DEPARTURE (REBAS ONE) FROM SAN FRANCISCO RUNWAY 28 — EQUIPMENT COMPLEMENT 1**



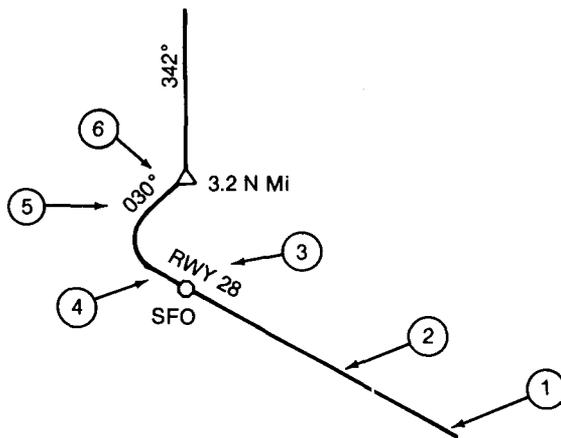
1. Crew sets MLS receivers 1 and 2 to the MLS frequency, selects the back azimuth function, and sets the bearing to 342 and the range to 3.2.
2. Crew engages autopilot and VOR/LOC mode after attaining positive rate of climb. Crew monitors turn.
3. Crew monitors rollout and DME to way point.
4. When at 0.5 DME, crew changes range to 10.0 (REBAS). Crew monitors turn onto course.

**FIGURE 16. GUIDANCE PROCEDURES FOR AN MLS PRECISION QUIET NINE DEPARTURE FROM SAN FRANCISCO RUNWAY 28 — EQUIPMENT COMPLEMENT 2**



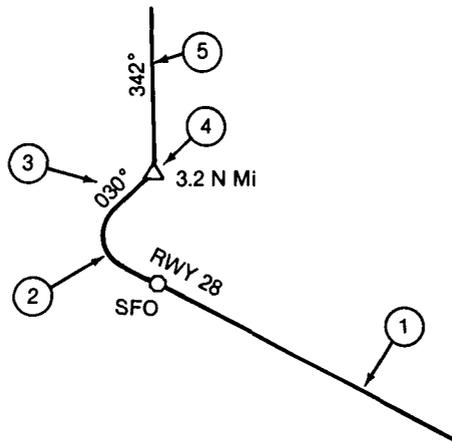
1. Crew enters Quiet Eight Departure into route plan on CDU and executes. Crew tunes MLS Receivers 1 and 2 to MLS frequency.
2. Crew engages autopilot and LNAV mode after attaining positive rate of climb. Crew monitors turn.
3. Crew monitors rollout to 030.
4. Crew monitors turn to 342.

**FIGURE 17. GUIDANCE PROCEDURES FOR AN MLS PRECISION QUIET NINE DEPARTURE FROM SAN FRANCISCO RUNWAY 28 — EQUIPMENT COMPLEMENT 3**



1. Approach control assigns missed approach procedures with the approach path if they differ from the published procedures.
2. Crew engages go-around mode.
3. Crew sets bearing to 342, range to 3.2, and back azimuth function.
4. Crew monitors BAZ valid annunciation. When valid, crew engages VOR/LOC mode and monitors turn.
5. Crew monitors rollout and DME to way point.
6. When at 0.5 DME, crew sets range to 10.0. Crew monitors turn onto course.

**FIGURE 18. GUIDANCE PROCEDURES FOR AN MLS MISSED APPROACH TO SAN FRANCISCO RUNWAY 28 USING QUIET NINE DEPARTURE — EQUIPMENT COMPLEMENT 2**



1. Approach control assigns missed approach procedures with the approach path if they differ from the published procedures. Crew enters missed approach into active route via the CDU.
2. Crew engages the go-around mode.
3. Crew monitors turn.
4. Crew monitors rollout to 030.
5. Crew monitors turn to 342.

**FIGURE 19. GUIDANCE PROCEDURES FOR AN MLS MISSED APPROACH TO SAN FRANCISCO RUNWAY 28 USING QUIET NINE DEPARTURE — EQUIPMENT COMPLEMENT 3**

## WORKLOAD ANALYSIS

The workload program was developed to verify workload improvement in the MD-80, compared to the DC-9-50, and to demonstrate compliance with the Federal Aviation Regulations. Details of this program are described in Stone, Gulick, and Gabriel (Reference 4). This program uses a task-timeline analysis methodology to define and quantify workload. The primary measure is the ratio of time a task requires to time available within flight constraints.

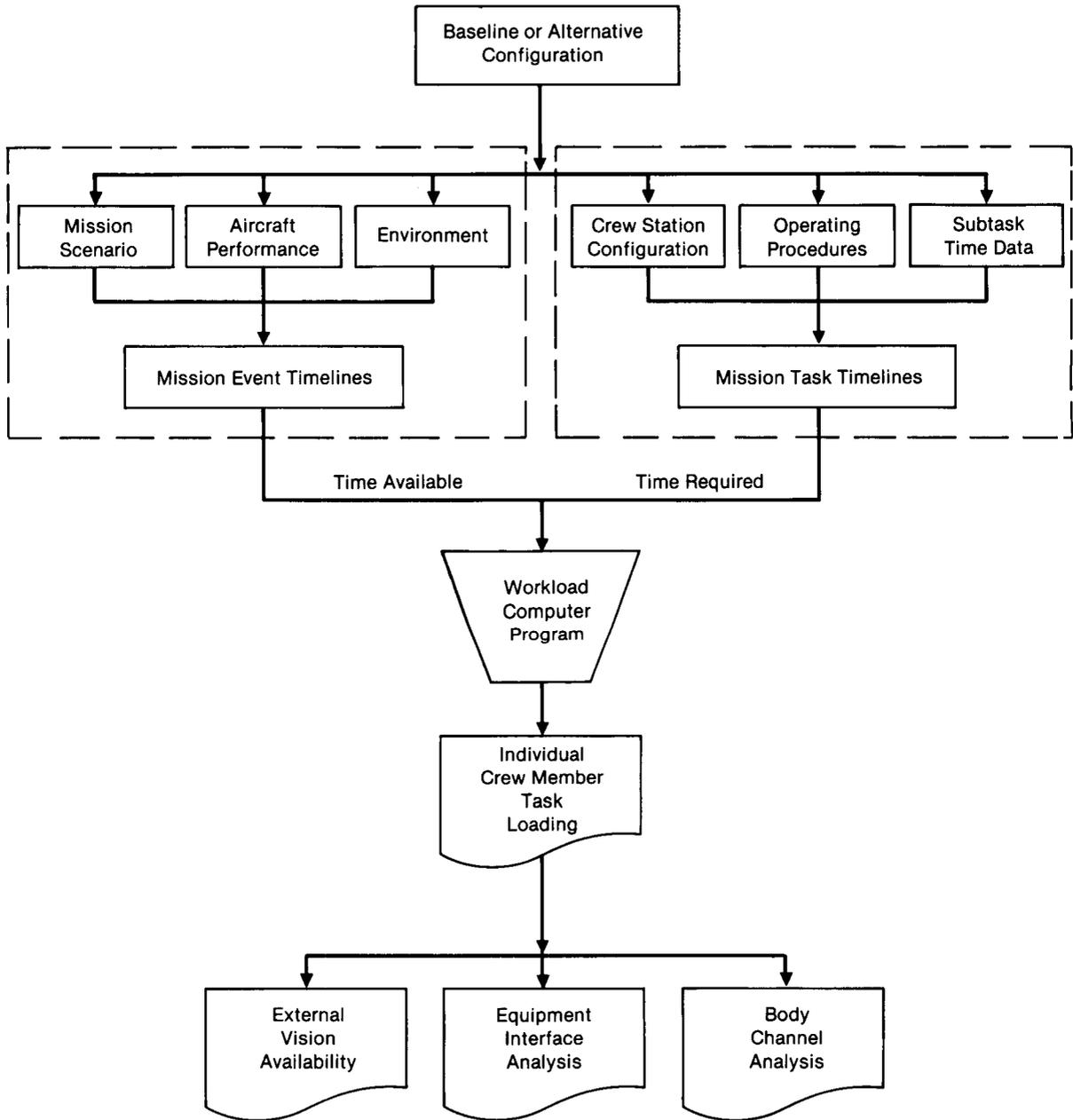
Figure 20 shows the analytical steps used in the workload program. Initially, mission analysis is employed to determine the parameters of the functional system in which crew and equipment operate. Mission analysis is used to organize the flight into phases and segments, and the segments are used as a framework to identify tasks and subtasks which occur within the segments.

This task analysis represents a baseline to establish a store of crew/equipment data. At this level information is compiled, including the time required to complete each subtask, from previous missions and studies. The computer program sums each crew member's task times and relates this to the time available in each mission segment. This provides a workload index, which is the ratio of time required to time available. These measures are combined on a time-weighted average to provide an assessment of workload for each flight segment, as well as an overall average for the entire flight.

Since the program treats all subtasks as occurring in series and does not reflect the capability of parallel processing, the workload values are conservative estimates. However, it treats continuous tasks as being discrete and occurring in a finite period, which underestimates their workload. Unless contingencies or errors — which tend to increase the task times — are built into the scenario, the workload program does not compensate for them. The program only considers the following activities: limb movements, eye movements, listening, and voice communication. It does not consider any cognitive or mental activities or differences in individual abilities. If the tasks vary significantly in mental workload (e.g., memory and attention demands), the task-timeline analysis methodology may not be sensitive to workload differences.

The program is only used for comparative analysis. If the baseline scenario used for the comparison is acceptable, the compared system's workload will be acceptable if it is the same or lower than the baseline. If the difference in workload is greater than 30 percent or the total workload for one crew member is greater than 70 percent, it will be considered unacceptable.

The basic MD-80 scenario described by Stone, et al (Reference 4), was a round-robin flight from Los Angeles International Airport to Stockton and back to Los Angeles. The flight used an autopilot and autothrottles and there were no contingency operations. The descent phase of the scenario was a Sadde One arrival from Fillmore for an ILS approach to L.A. Runway 25. This study modified the scenario for an arrival to Burbank Runway 7 from the Fillmore intersection, and was used as the ILS baseline for the comparative analysis. The same amounts of traffic and ATC communications were used in all of the arrivals. Using the same basic crew tasks, an MLS segmented approach was developed from Fillmore to Burbank Runway 15. The remaining scenarios were constructed in the same manner by modifying the baseline scenario.



**FIGURE 20. CREW STATION WORKLOAD ANALYSIS AND DESIGN SYSTEM**

Workload indexes were obtained for the flight segments between descent and rollout. A graph of these indexes is shown in Figure 21 for the ILS approach to Burbank Runway 7. Each flight segment is identified in this figure. The different approach scenarios were compared two at a time by overlaying graphs of their indexes. Equipment Complement 2 approaches were compared to the ILS approaches, and equipment Complement 3 approaches were compared to Complement 2 approaches. This allowed comparison of workload differences by flight segment.

### **ILS Approach**

The basic crew functions for the ILS approach are the following:

1. Selecting and engaging the autopilot and autothrottle modes via the glareshield panel.
2. Tuning the radio navigation and communication receiver frequencies.
3. Engaging the secondary controls and landing gear.
4. Monitoring performance and systems, including verification via the cockpit displays.
5. ATC communications.
6. Intracockpit communications.
7. Monitoring and callout of localizer and glide slope captures, markers, and altitudes.
8. Scanning the outside visual environment for traffic and the runway.

These activities are divided between the two crew members. The captain or pilot flying is mainly responsible for items (1), (4) and (6), the first officer is responsible for items (2), (3), (5), and (7), and both share responsibility for item (8). These activities represent the differences in workload between the two crew members, as shown in Figure 21.

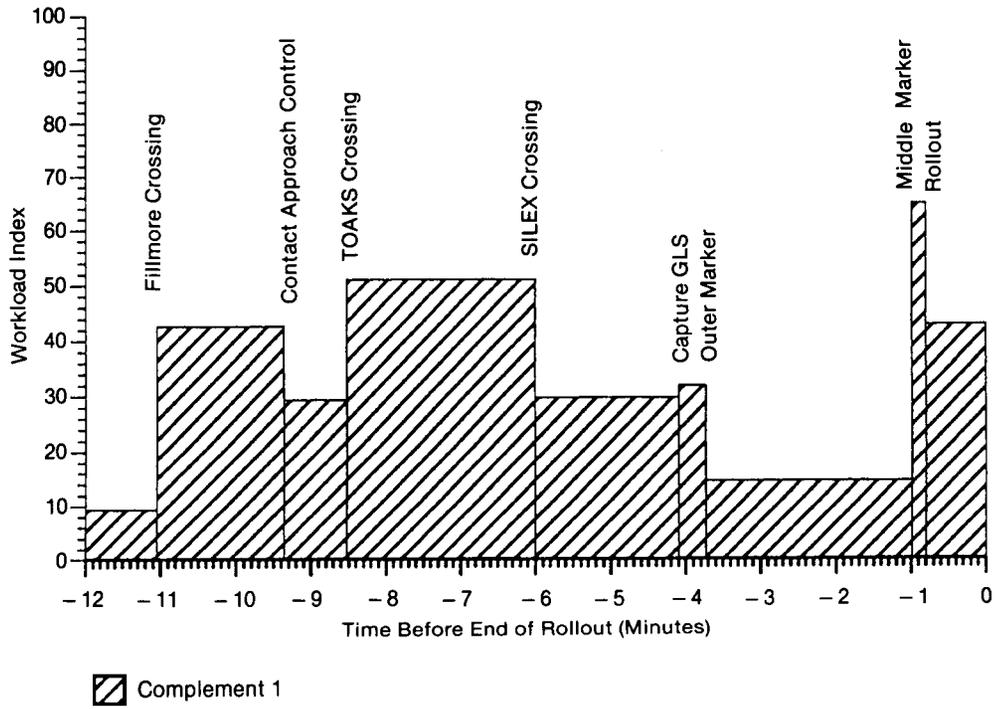
Figure 22 shows the workload comparison for equipment Complements 1 and 3. This scenario assumes that ATC vectors the aircraft straight in from Toaks and the crew does not alter the flight plan. Complement 3, which includes the flight management system, shows a lower workload index for selecting and engaging the guidance functions. The primary reduction is in the captain's workload. After intercepting the ILS, the workload is the same as for Complement 1.

### **MLS Segmented Path Approach**

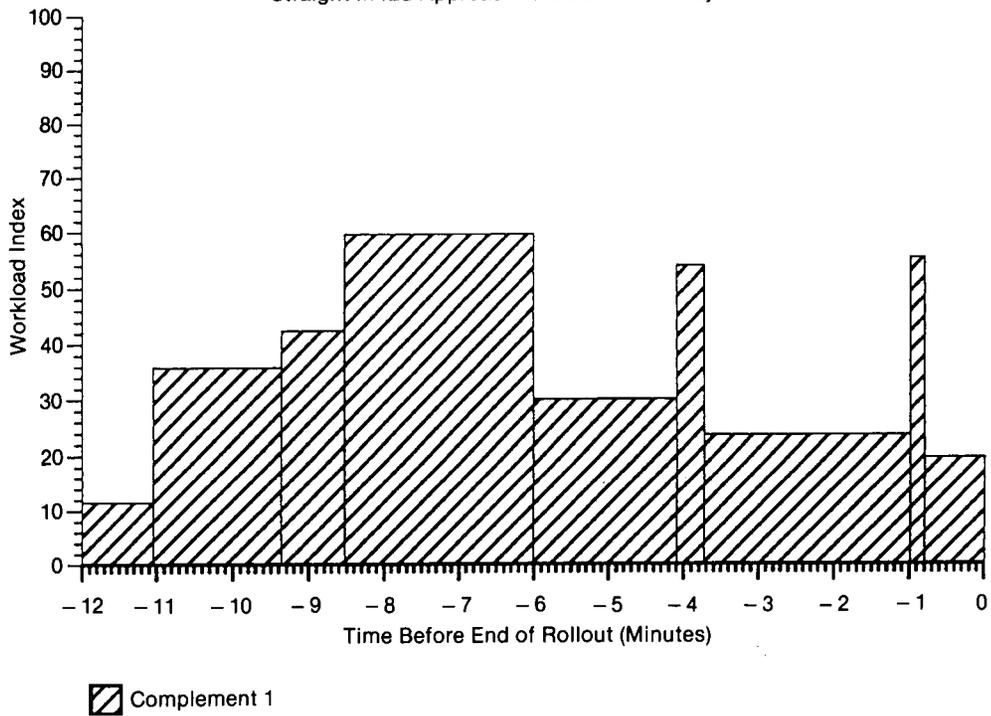
The main differences between the MLS segmented and the ILS approach scenarios are the following:

- The MLS scenario is a minute shorter.
- ATC clears the aircraft for the MLS approach from the 087 radial without vectors. There are no turns before the final MLS leg.
- After 5,000 feet, there are no altitude transitions until the glide slope is intercepted.
- The crew inserts the course and range for the MLS way point before capture and for the ground point intercept before reaching the way point.

**CAPTAIN'S WORKLOAD**  
Straight-in ILS Approach to Burbank Runway 7

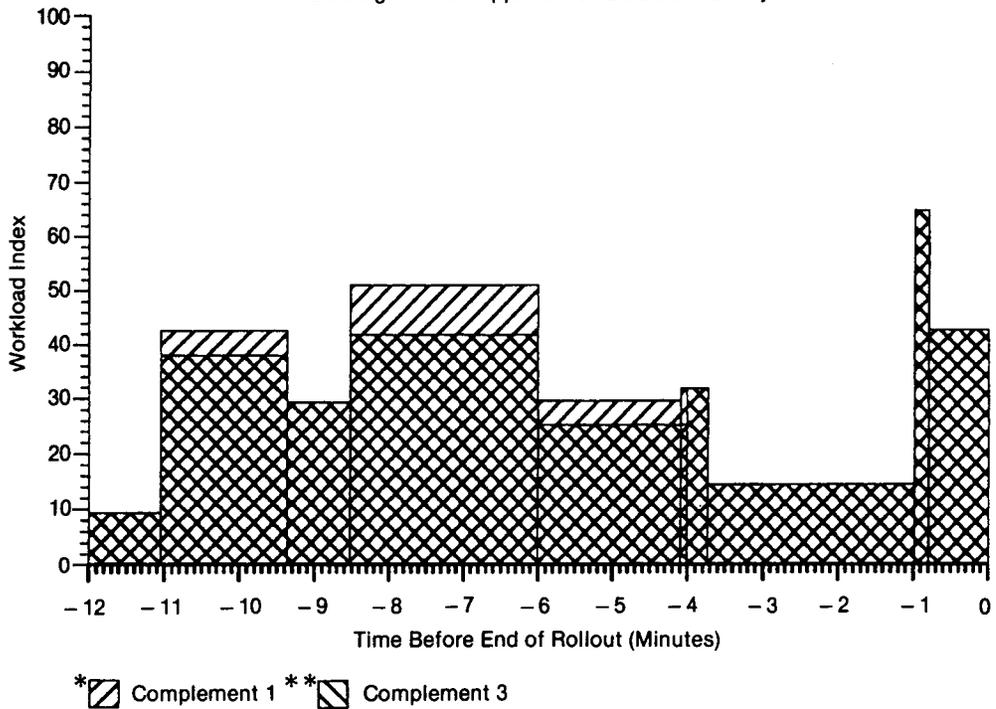


**FIRST OFFICER'S WORKLOAD**  
Straight-in ILS Approach to Burbank Runway 7

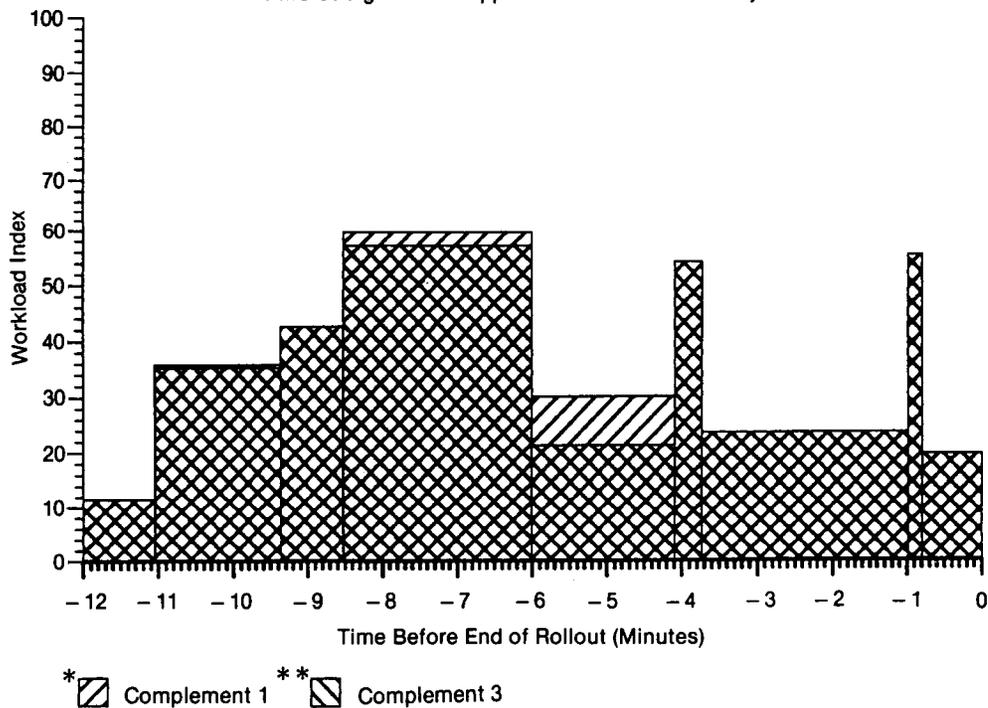


**FIGURE 21. WORKLOAD INDEXES FOR THE ILS APPROACH**

**CAPTAIN'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 FMS Straight-in ILS Approach to Burbank Runway 7\*\*



**FIRST OFFICER'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 FMS Straight-in ILS Approach to Burbank Runway 7\*\*



**FIGURE 22. WORKLOAD COMPARISON FOR ILS APPROACHES**

The shorter scenario compresses the workload, while eliminating the turn and altitude transition reduces the workload. These two factors counteract each other. A workload increase is shown in Figure 23 for those flight segments where the crew enters the bearing and range of the way points.

Figure 24 compares the workload for equipment Complements 2 and 3 for the MLS segmented approach. As with the ILS approach, Complement 3 shows a lower workload because the entering of guidance data is automatic and the crew is only required to monitor the aircraft's performance. However, the workload still increases for the final leg.

### **MLS Multisegmented Path Approach**

Part of the difference between the multisegment and the ILS workloads is the difference in approach paths. The multisegmented MLS approach has a long stretch between the Palmdale VOR and the Lynxx Two way point, compared to the short distance on the ILS approach between the Fillmore VOR and Toaks way point. Since the same crew activity occurs in both of these segments, the MLS workload index is lower, as shown in Figure 25. The workload index beyond these segments is higher for the MLS approach because the crew must enter way point bearing, elevation, and range on both the MLS 1 and 2 receivers three different times — once for each of the three remaining flight segments illustrated in Figure 10. This workload is significantly reduced with equipment Complement 3, as shown in Figure 26, since these way points are automatically entered by the FMS.

### **MLS Segmented Glide Slope Approach**

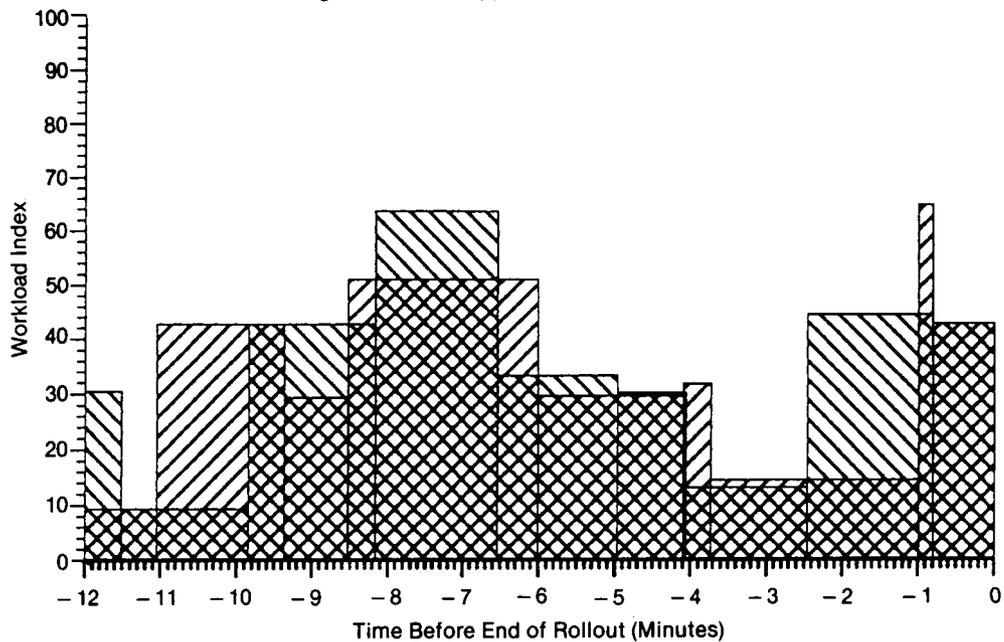
As in the multisegmented approach, the segment between Palmdale and the Ezras way point is longer than the equivalent segment in the ILS approach. This reduces the workload index for this flight segment, as shown in Figure 27. After the Ezras way point, the segmented glide slope approach has no further turns and no altitude transitions from 7,000 feet until the 5-degree glide slope is intercepted. This reduces the crew's activity after glide slope capture. As the way point is approached, crew activity increases because they must enter the glide slope data and monitor the transition. Utilizing the flight management system in Complement 3 has little effect on this scenario except for the final glide slope transition at MLS01, as shown in Figure 28.

### **Precision Departures**

The original Douglas Aircraft workload program was a Gorman Four departure from Los Angeles. This departure was modified for a Rebas One departure and a Quiet Nine MLS precision departure from San Francisco. The flight segments from ready for takeoff to reaching 1,500 feet were included and are the only segments that will be influenced by the MLS procedures. The increase in workload after takeoff will be monitoring the initial turn to course 030 and, depending on the equipment complement, entering the second way point data before reaching the first way point.

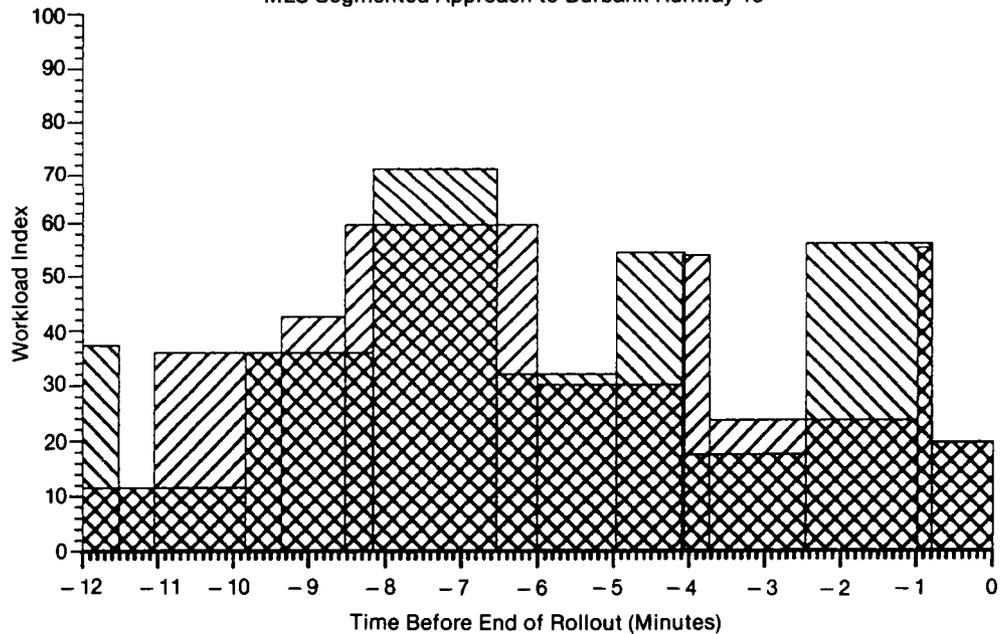
Figure 29 shows the comparison between the normal and the MLS departure using equipment Complement 2. This shows a workload increase for the final segment, because the crew must enter way point

**CAPTAIN'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 MLS Segmented Path Approach to Burbank Runway 15\*\*



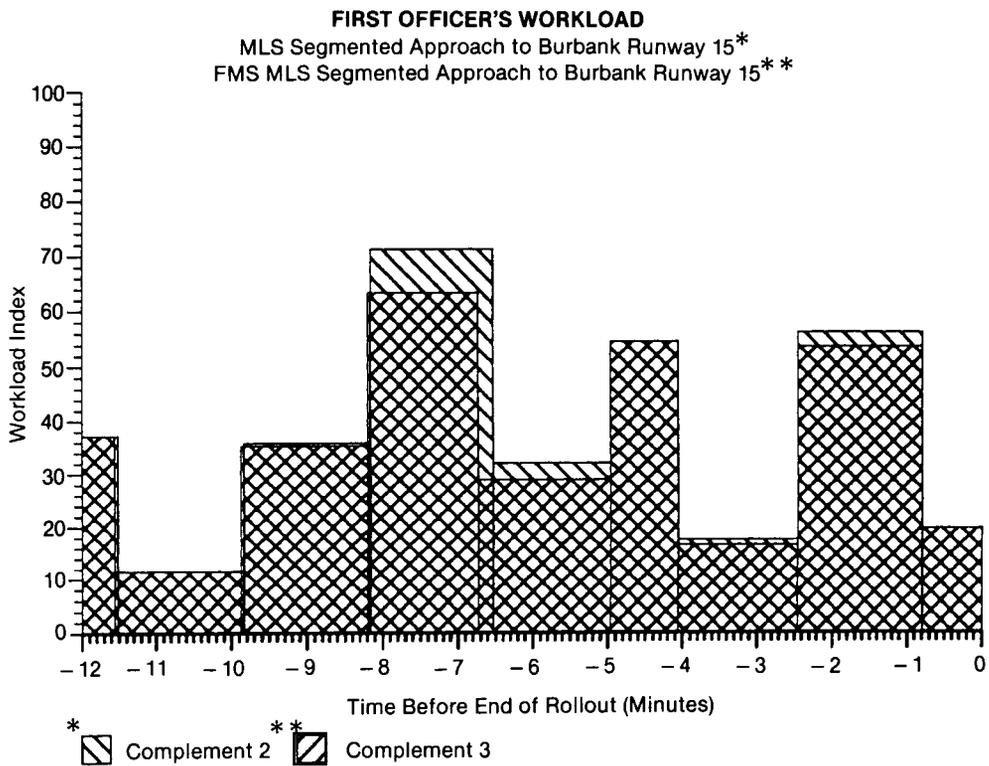
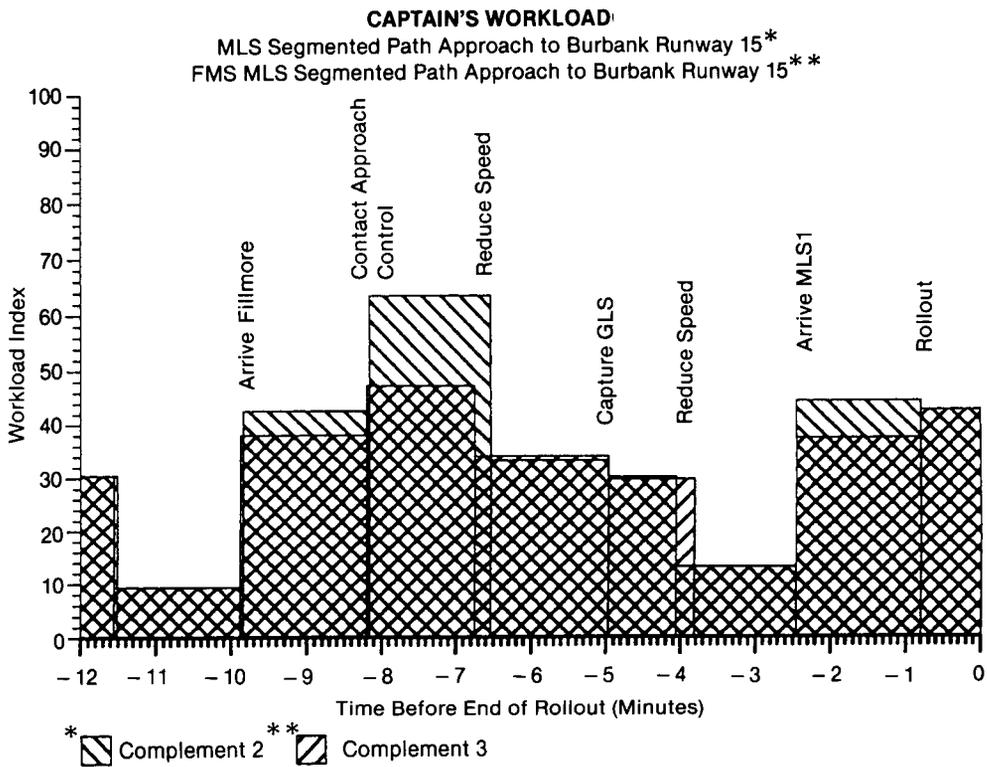
\* Complement 1    \*\* Complement 2

**FIRST OFFICER'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 MLS Segmented Approach to Burbank Runway 15\*\*



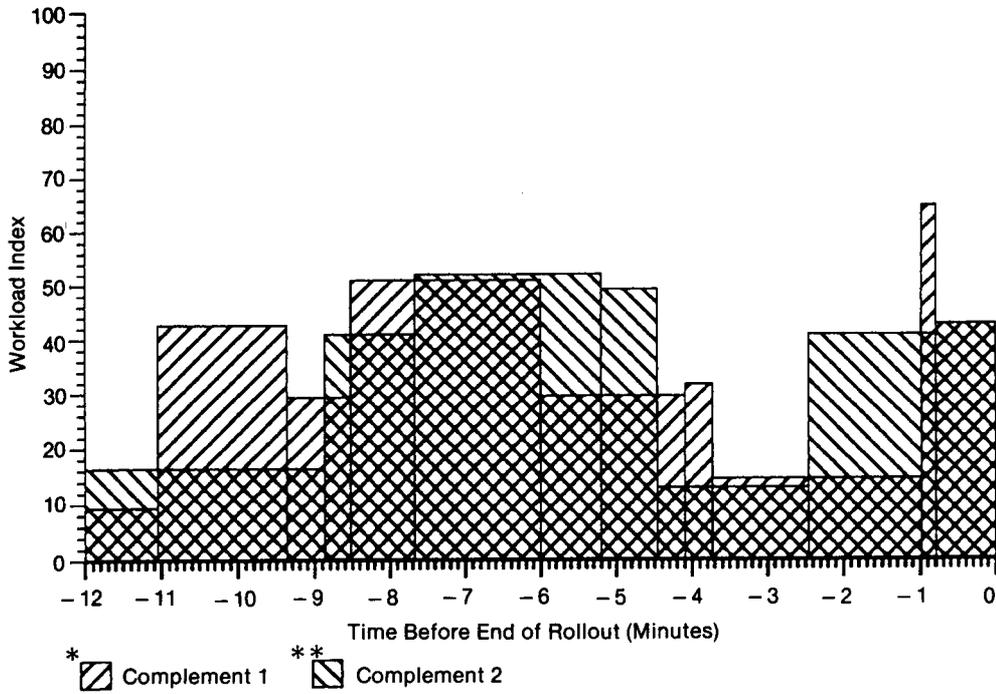
\* Complement 1    \*\* Complement 2

**FIGURE 23. WORKLOAD COMPARISON OF MLS SEGMENTED AND ILS APPROACHES**

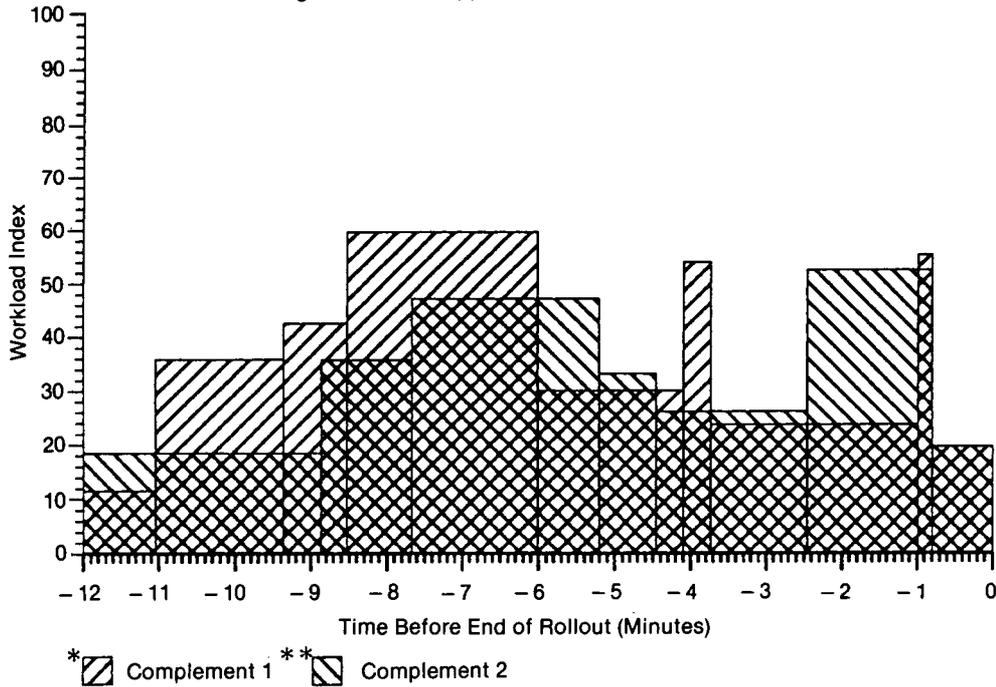


**FIGURE 24. WORKLOAD COMPARISON OF MLS SEGMENTED APPROACHES**

**CAPTAIN'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 Multisegmented MLS Approach to Burbank Runway 15\*\*

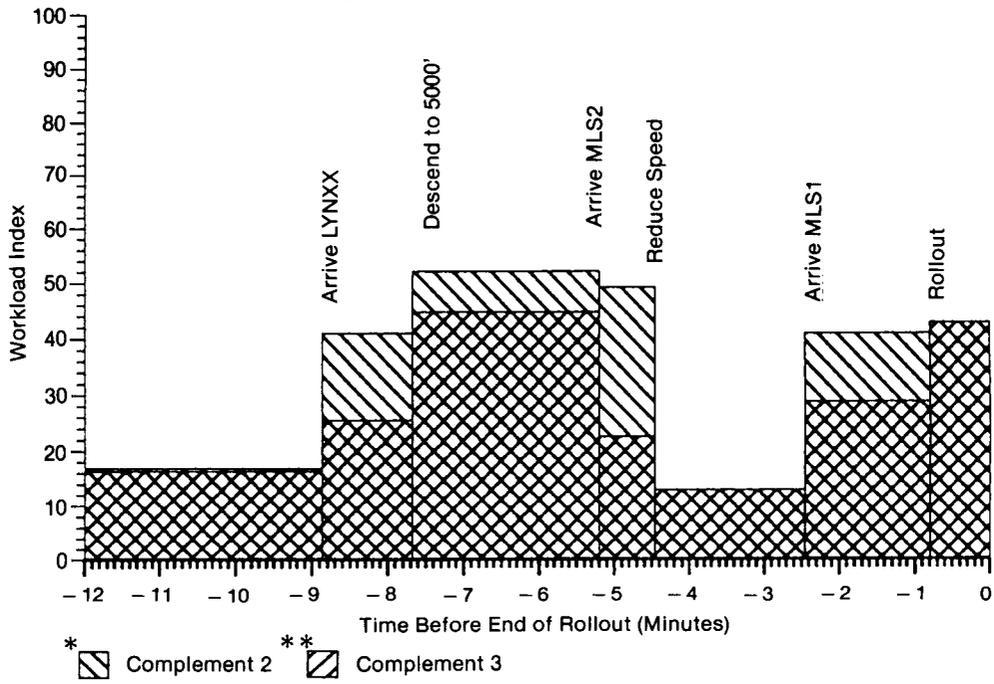


**FIRST OFFICER'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 Multisegmented MLS Approach to Burbank Runway 15\*\*

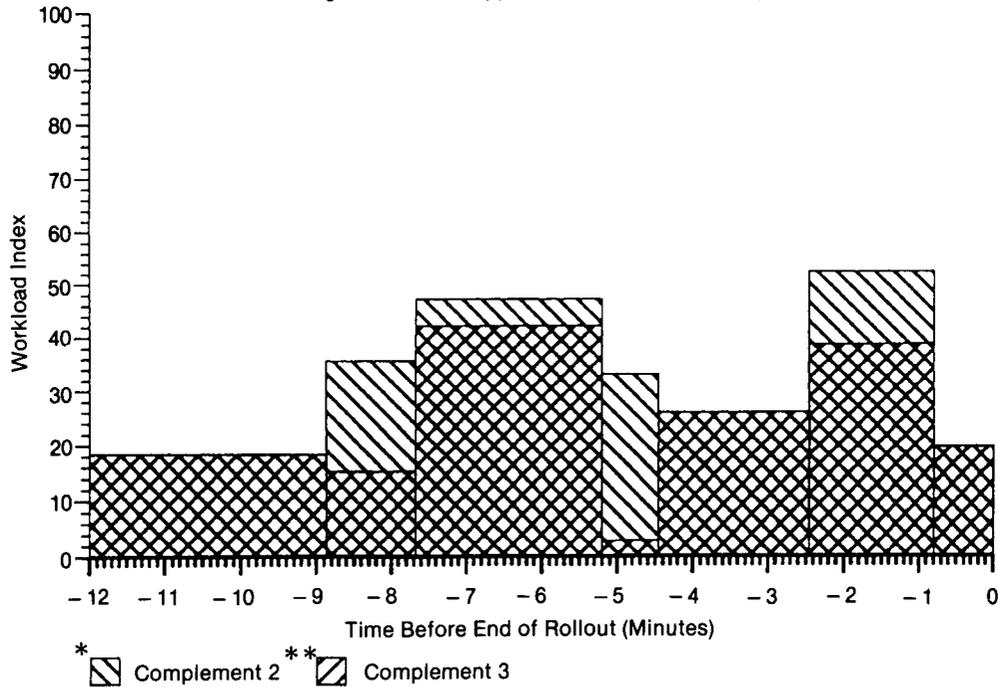


**FIGURE 25. WORKLOAD COMPARISON OF MLS MULTISEGMENTED AND ILS APPROACHES**

**CAPTAIN'S WORKLOAD**  
 Multisegmented MLS Approach to Burbank Runway 15\*  
 FMS Multisegmented MLS Approach to Burbank Runway 15\*\*

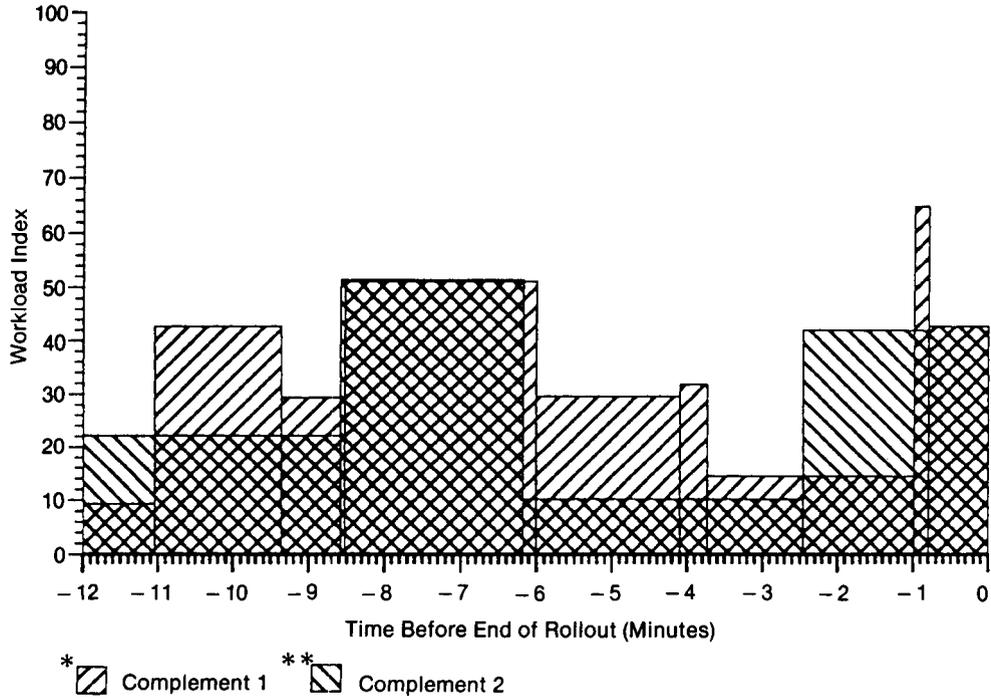


**FIRST OFFICER'S WORKLOAD**  
 Multisegmented MLS Approach to Burbank Runway 15\*  
 FMS Multisegmented MLS Approach to Burbank Runway 15\*\*

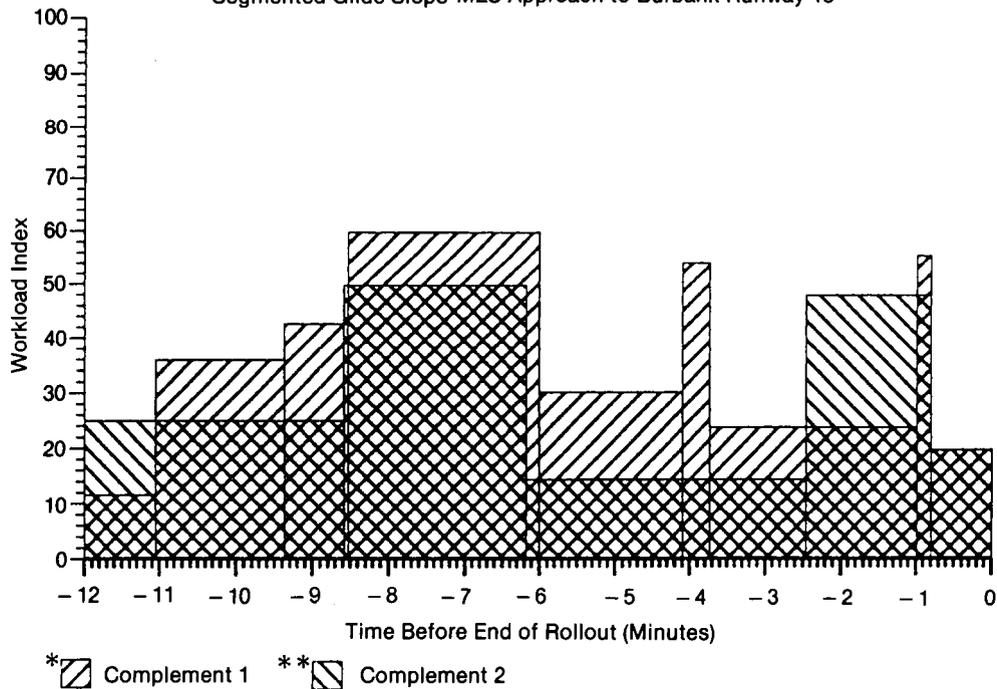


**FIGURE 26. WORKLOAD COMPARISON OF MULTISEGMENTED APPROACHES**

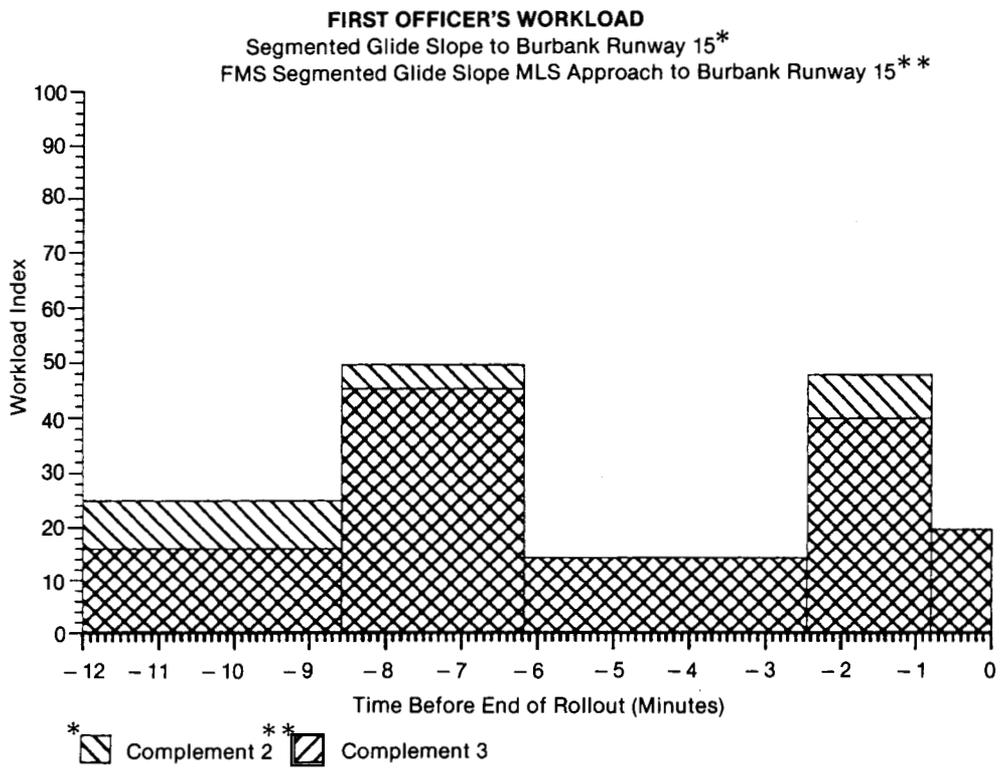
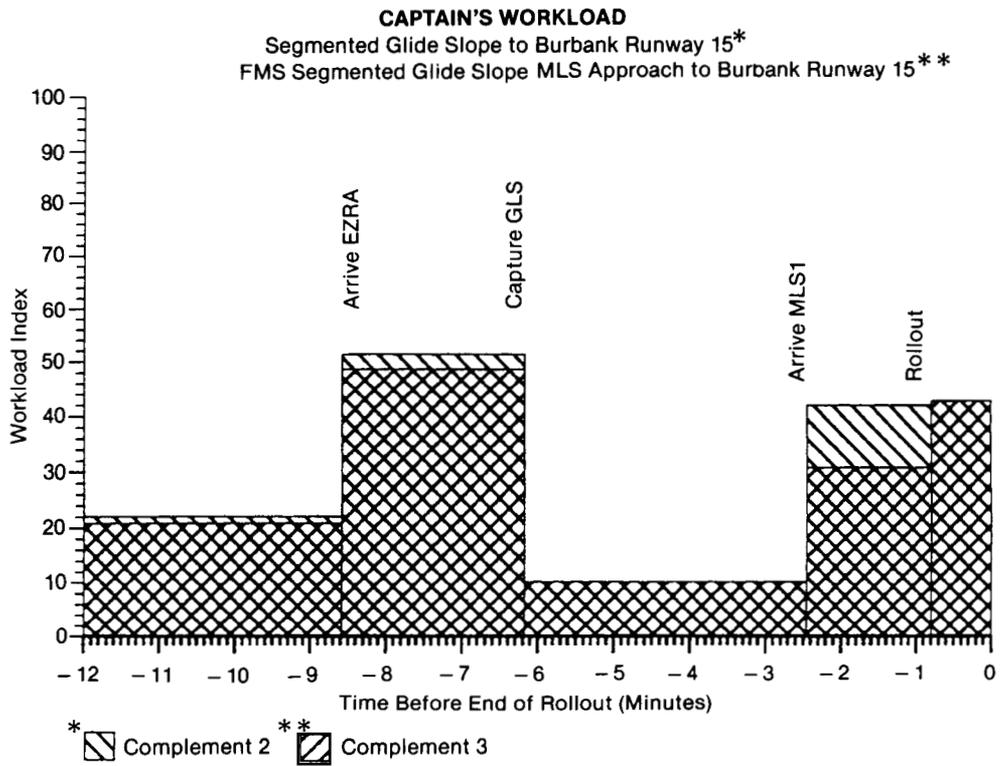
**CAPTAIN'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 Segmented Glide Slope MLS Approach to Burbank Runway 15\*\*



**FIRST OFFICER'S WORKLOAD**  
 Straight-in ILS Approach to Burbank Runway 7\*  
 Segmented Glide Slope MLS Approach to Burbank Runway 15\*\*

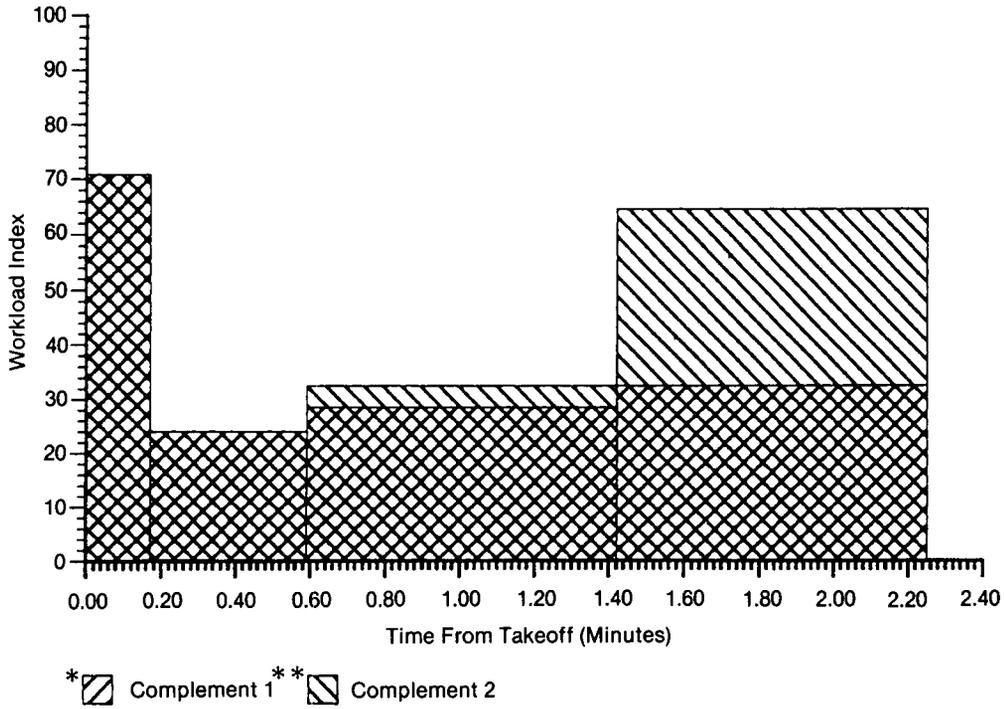


**FIGURE 27. WORKLOAD COMPARISON OF SEGMENTED GLIDE SLOPE AND ILS APPROACHES**

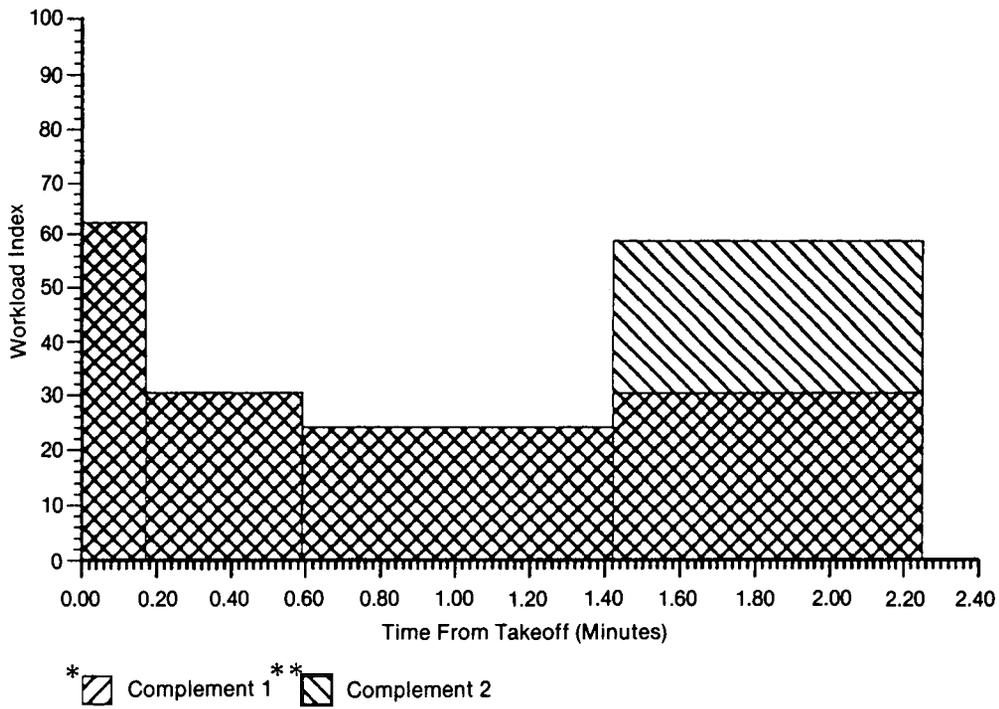


**FIGURE 28. WORKLOAD COMPARISON OF SEGMENTED GLIDE SLOPE APPROACHES**

**CAPTAIN'S WORKLOAD**  
 Normal Departure from SFO 28\*  
 MLS Precision Departure from SFO 28\*\*



**FIRST OFFICER'S WORKLOAD**  
 Normal Departure from SFO 28\*  
 MLS Precision Departure from SFO 28\*\*



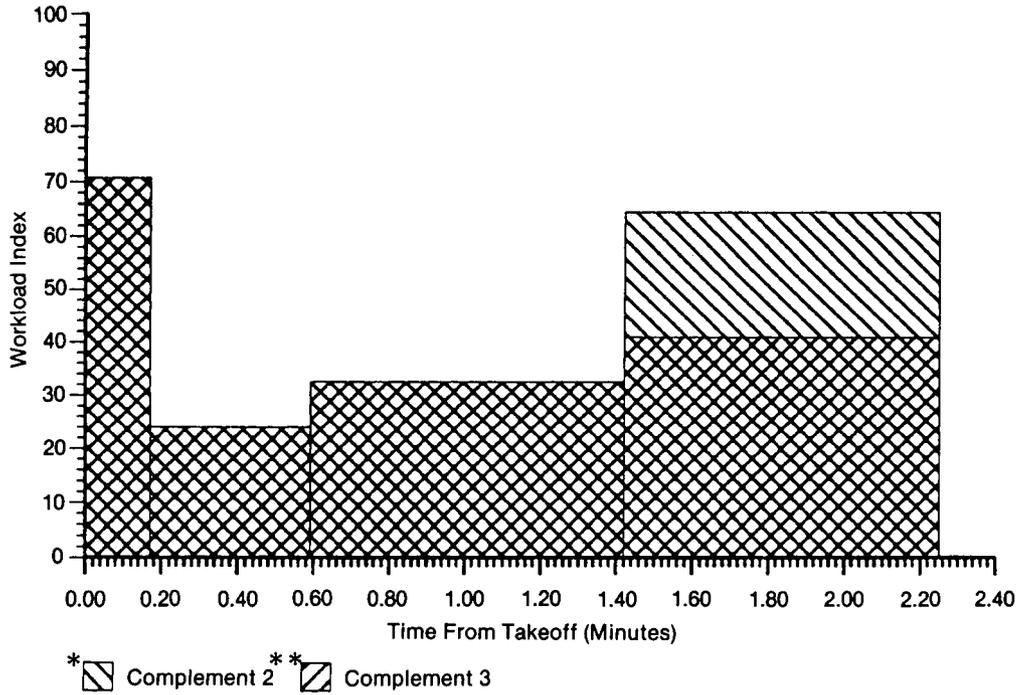
**FIGURE 29. WORKLOAD COMPARISON OF PRECISION AND NORMAL DEPARTURES**

data into the MLS receiver. Another procedure would be to tune the receiver to the San Francisco VOR and enter the 342 course. These steps will require about the same amount of work. Figure 30 compares equipment Complements 3 and 2. With the FMS, the way points will be entered into the flight management computer before takeoff and there is little increase in workload compared to the normal departure.

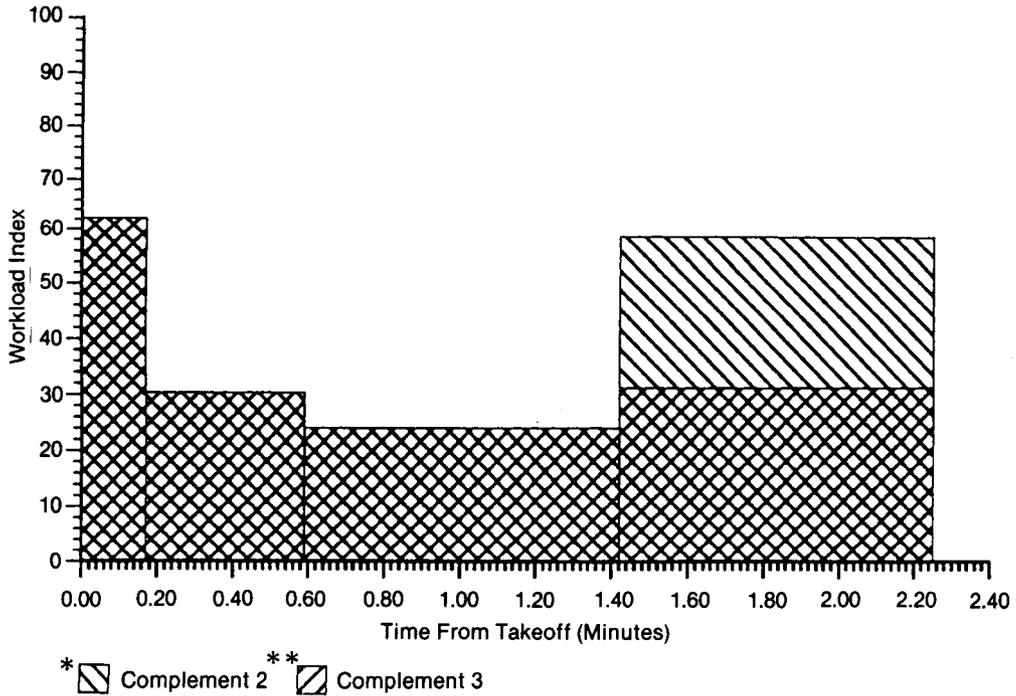
### **Missed Approaches**

The missed approach scenarios were not analyzed with the workload program because the original Douglas workload program did not have any missed approach scenarios. Inspection of the crew tasks with equipment Complement 2 indicates that the workload will increase during a normal missed approach. This increase is due to the additional tasks of switching to the back azimuth function, entering the bearing and range of the way points, and engaging the localizer. With equipment Complement 3, most of these operations occur automatically and the only workload increase will be in preloading the missed approach path into the FMS. Missed approaches with equipment Complement 3 will have little impact on overall workload.

**CAPTAIN'S WORKLOAD**  
 MLS Precision Departure from SFO 28\*  
 MLS (Comp 3) Precision Departure from SFO 28\*\*



**FIRST OFFICER'S WORKLOAD**  
 MLS Precision Departure from SFO 28\*  
 MLS (Comp 3) Precision Departure from SFO 28\*\*



**FIGURE 30. WORKLOAD COMPARISON OF PRECISION DEPARTURES**

## DISCUSSION

This analysis assumes that MLS airborne equipment will provide course deviation signals to the autopilot and that the crew will operate the aircraft in the autopilot mode. For this case, the impact of MLS operations on crew workload will be selecting the approach path and monitoring aircraft position and performance. For a straight-in ILS "look-alike" approach, these will be only a small workload increase compared to an ILS approach. This increase is attributable to the selection of the azimuth and elevation angle on the MLS control panel.

Complex approaches with the second equipment complement will have a significant increase in workload. This is due to the crew entering way point data into the computer on-line. For the complex approaches analyzed in this study, the workload was within the capacity of two crew members. However, for approaches with more than two segments or with the way points closer together, the workload may exceed the criteria level established for this study.

Complex approaches with the third equipment complement using a flight management computer will have a workload equivalent to normal ILS approaches, or possibly lower. This is due to the elimination of the data entry task and a reduction in ATC communications. However, with equipment Complement 3 there are a number of conditional procedures that could increase the crew tasks. These procedures may include:

- ATC vectoring the aircraft before approach path intercept, or altering the approach path by extending or inserting a leg.
- ATC assigning a flight path that is not already stored in the flight management computer.
- An autoland disconnect requiring the crew to fly the approach path manually using the flight director.

It is assumed that the above procedures will increase the workload and — depending upon the time available — they may exceed the crew's capacity. It is recommended that future studies examine the impact of these conditional procedures on crew tasks and workload.

For precision departures, equipment Complement 2 will have a significant increase in workload over a normal departure because the crew will manually switch to the localizer and enter way point data after establishing a positive rate of climb. This analysis shows that the workload for these procedures is within the crew's capacity, but only marginally. For equipment Complement 3, the workload is equivalent to the normal departure.

Crew procedures defined in this study are generalized and may vary depending upon the airborne equipment used. The workload values presented are only estimates based on these generalized procedures, and are only intended to be used as an initial comparative analysis with conventional ILS procedures. They do not include estimates of mental or cognitive workload and they do not compensate for errors in task execution. Cockpit simulator studies are recommended to measure crew performance and

workload for various MLS approaches and departures, using both autopilot and manual flight director approaches. Even with simulation studies it may be difficult to measure crew workload because it is difficult to implement a full-task simulation.

The MLS's greater flexibility makes it possible for crew members to introduce more errors than during conventional ILS approaches. For example, the wrong course or glide slope angle could be entered into the navigation computer, which would not only increase the workload but affect mission reliability and safety. Procedures should be developed to reduce the possibility of making errors. It is recommended that future studies investigate the impact of crew errors in MLS operations and address such issues as data-entry errors, rates and consequences of errors, and methods to reduce or prevent them.

### REFERENCES

1. Knox, C.E., Flying Complex Approach Path Using the Microwave Landing System, SAE Technical Paper 861771, Aerospace Technology Conference, Long Beach, California, October 1986.
2. Feather, J.B., Guidance Studies for Curved, Descending Approaches Using the Microwave Landing System (MLS), NASA CR-178030, May 1986.
3. Feather, J.B., Guidance Law Simulation Studies for Complex Approaches Using the Microwave Landing System (MLS), NASA CR-178182, November 1986.
4. Stone, G., Gulick, R.K., and Gabriel, R.F., Use of Task/Timeline Analysis to Assess Crew Workload, Douglas Paper 7592, Douglas Aircraft Company, Long Beach, California, July 1985.
5. RTCA Committee SC-151, Minimum Operational Performance Standard for Airborne MLS Area Navigation Equipment, Eleventh Draft. RTCA Paper No. 333-87/SC151-184, Radio Technical Commission for Aeronautics, Washington, D.C., July 1987.



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16. Abstract The objective of this study was to identify crew procedures involved in Microwave Landing System (MLS) operations and to obtain a preliminary assessment of crew workload. The crew procedures were identified for three different complements of airborne equipment coupled to an autopilot. Using these three equipment complements, crew tasks were identified for MLS approaches and precision departures and compared to an ILS approach and a normal departure. Workload comparisons between the approaches and departures were made by using a task-timeline analysis program that obtained workload indexes, i.e., the ratio of time required to complete the tasks to the time available. The results showed an increase in workload for the MLS scenarios for one of the equipment complements. However, even this workload was within the capacity of two crew members.					
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